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LEAD AND ZINC ORES *of* PENNSYLVANIA

By

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LETTER OF TRANSMITTAL.

R. Y. Stuart, Secretary,
Department of Forests and Waters.

Sir:

Recent years have seen a revival of interest in mining lead and zinc in Pennsylvania notwithstanding that all of the old lead and zinc mines have long been closed. Several companies have been organized and have undertaken prospecting. The offerings of stock in some of these companies brought many inquiries to the Geological Survey for information regarding these deposits. During 1923-24 one company has spent several thousand dollars prospecting with diamond drills for zinc ore at Friedensville. As the principal data on the subject were reports 30 years old I asked Prof. B. L. Miller, head of the Department of Geology, Lehigh University, to visit the localities where these ores have been mined and to prepare a report which would meet the needs of the Survey in answering the questions of prospective investors.

Professor Miller is particularly qualified to make such a report because he has studied the occurrence of lead and zinc ores in Pennsylvania and in other parts of North and South America both scientifically and professionally for a number of years.

In this report a history is given of each of the mining operations, and the occurrence and character of the ore are described. It is recounted that lead ore was mined in Blair County in 1778 to supply bullets for the Revolutionary War, and before 1810 lead ore was being mined near Phoenixville, within 25 miles of Philadelphia. The ore at Bamford and at New Galena was discovered by men digging holes for fence posts. The second successful attempt to manufacture zinc oxide in the United States was accomplished at South Bethlehem in 1853, and the production of spelter from zinc ore mined at Friedensville began in 1859. What was at the time the largest pumping engine in the world was installed at a zinc mine at Friedensville in 1872, and attracted wide attention from the engineering profession. This pump was the object of a special visit by the American Institute of Mining Engineers because it had a rated capacity of 12,000 gallons a minute.

One mine alone produced about 300,000 tons of zinc ore. Evidence is arrayed to show why it may confidently be expected that commercial bodies of these ores may yet be found.

Professor Miller points out that certain of the deposits have not been exhausted, and cites the difficulties that must be expected in reopening and mining these deposits. With equal emphasis he announces his belief in the worthlessness of supposed deposits at other places.

This report therefore will serve miners and investors as a guide to development in the more favorable places, and as a warning against spending money and labor in attempts to develop mines in those places where all the evidence is against the success of such an undertaking. It is confidently believed that this report, prepared and printed for a few hundred dollars, will be worth many thousands of dollars to the citizens of Pennsylvania.

Respectfully,

Geo. H. Ashley

State Geologist.

April, 1924.

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LEAD AND ZINC ORES OF PENNSYLVANIA.

By

Benjamin LeRoy Miller.

SUMMARY

Lead and zinc minerals are not unusual in the rocks of Pennsylvania, although in most places they exist in such small quantities as to be of interest only to the mineralogist. These minerals occur mostly in the belt of greatly folded strata that sweeps across the eastern and central portions of the State from New Jersey to Maryland. They are found mainly in limestones, shales, and sandstones, but are present in some of the gneisses and serpentines. Igneous dike rocks associated with the ores in a few places suggest genetic connection between them. However, in most of the places where the lead and zinc minerals occur, igneous rocks have not been found. It is believed that the minerals were concentrated by and precipitated from meteoric waters, probably of artesian character.

Serious attempts have been made to mine these minerals in Sinking Valley and near Birmingham, Blair County; northwest of Doylestown, Bucks County; north of Bellefonte, Centre County; south and east of Phoenixville in Chester and Montgomery counties; near Espy, Columbia County; northeast of McConnellstown, Huntingdon County; north of Marticville and northeast of Bamford, Lancaster County; at Friedensville, Lehigh County; and near Selinsgrove Junction, Northumberland County.

The Blair County mines were worked during the Revolutionary War to supply part of the lead needed for bullets for Washington's army. A story to the effect that the Bucks County mines were worked for the same purpose has not been verified. Practically all the mining of lead and zinc ores of the State was done during the latter half of the last century although some desultory work has been done during the last decade. All of the earliest mining was for lead ore alone as zinc ore was useless until in the late fifties when processes were perfected for the manufacture of zinc oxide and spelter from the Pennsylvania ores. Some of the lead ores contain a fair quantity of silver.

Several attempts have been made in recent years to obtain money by the sale of stock for the purpose of reopening the mines. In some instances the plans no doubt were legitimate but in others the

projects appear to have been promotion schemes for the sole benefit of the promoter. Prospective purchasers should investigate rather carefully the personnel of the directorate of any company that offers to sell stock in lead and zinc mines in Pennsylvania and also their plans for financing and operating.

The Friedensville zinc deposits have yielded more ore than any of the other districts. At the present time (April, 1924) the New Jersey Zinc Co., which owns these deposits, is operating five diamond drills in the vicinity of Friedensville in an attempt to determine the quantity of ore that remains. If the results are sufficiently encouraging, plans will probably be made for an early reopening of the mines.

The Phoenixville mines are second in importance among the lead and zinc mines of the State, both in the amount of ore already mined and in their future prospects. They are sufficiently promising to justify the expenditure of some money for prospecting and development, but it should be clearly understood by the investing public that considerable financial risk is involved. Some extremely fine ore remains in the mines and was seen by the writer in 1920 when one of the old mines was unwatered, but the quantity has not been determined.

The Bucks County mine also has yielded some very fine specimens of ore but no underground work has been done there in many years and the character and size of the ore body are problematical.

There seems to be little prospect that lead and zinc deposits at other places in the State can be developed into paying mines and it scarcely seems advisable to expend any money in prospecting them further. The Blair and Lancaster county deposits may still contain ore in paying quantities although this is doubtful. It was the opinion of the last operators that all the profitable ore had been exhausted when the mines were closed.

Pennsylvania does not possess sufficient lead and zinc ore to make it an important producer of these metals in comparison with other States but there is some hope that a few profitable mines may again be developed within its borders.

DISTRIBUTION OF LEAD AND ZINC MINERALS IN PENNSYLVANIA

Although Pennsylvania has produced only a few tons of lead and zinc ore in recent years there have been periods in the past when it was considered an important producer of these ores. On the whole the efforts to mine zinc and lead within the State have been disappointing although there are several districts where at different periods mines have been successfully operated. There are reasons for believing that in some of these places the deposits have not been exhausted and in 1923 three recently organized companies were seeking capital to reopen some of the old mines.

Lead and zinc minerals have been reported from a great many localities within the State. Both geographically and geologically they have a wide range. They are known to have been found in the following counties: Allegheny, Berks, Blair, Bradford, Bucks, Centre, Chester, Clearfield, Columbia, Delaware, Fayette, Huntingdon, Lackawanna, Lancaster, Lebanon, Lehigh, Lycoming, Montgomery, Northampton, Northumberland, Philadelphia, Schuylkill, Sullivan, Union, and York. There is no doubt that occasional specimens may be found in other counties.

Lead and zinc minerals are found in the ancient pre-Cambrian crystalline rocks of Philadelphia, Delaware, Chester, and Northampton counties; in the Cambro-Ordovician dolomitic limestones of Northampton, Lehigh, Lebanon, York, and Blair counties; in the Silurian sandstones of Lehigh and Centre counties; in the Devonian sandstones and shales of Monroe, Lycoming, and Sullivan counties; in the Devonian Helderberg limestones of Columbia, Northumberland, Union, and Huntingdon counties; in the Carboniferous sandstones and shales of Lackawanna, Schuylkill, Clearfield, Bradford, Fayette, and Allegheny counties; and in the Triassic shales and sandstones of Bucks, Montgomery, and Chester counties.

Most of these localities are of mineralogic interest only and their descriptions in the following pages should prevent the useless expenditure of money in further prospecting. The only districts where encouraging results have been obtained in prospecting and mining are the Friedensville district of Lehigh County, the Phoenixville mines of Chester and Montgomery counties, the Birmingham district of Blair county, the Bamford and Pequea mines of Lancaster County, and the New Galena district of Bucks County. Even in these localities mining projects have been disappointing and it has not been demonstrated that they still contain ores of economic importance. They are closed at present and the workings filled with water. For that reason the descriptions given in this report are necessarily, though not entirely, based mainly on old reports, some of which are of doubtful reliability, although an attempt has been made to evaluate properly the information available.

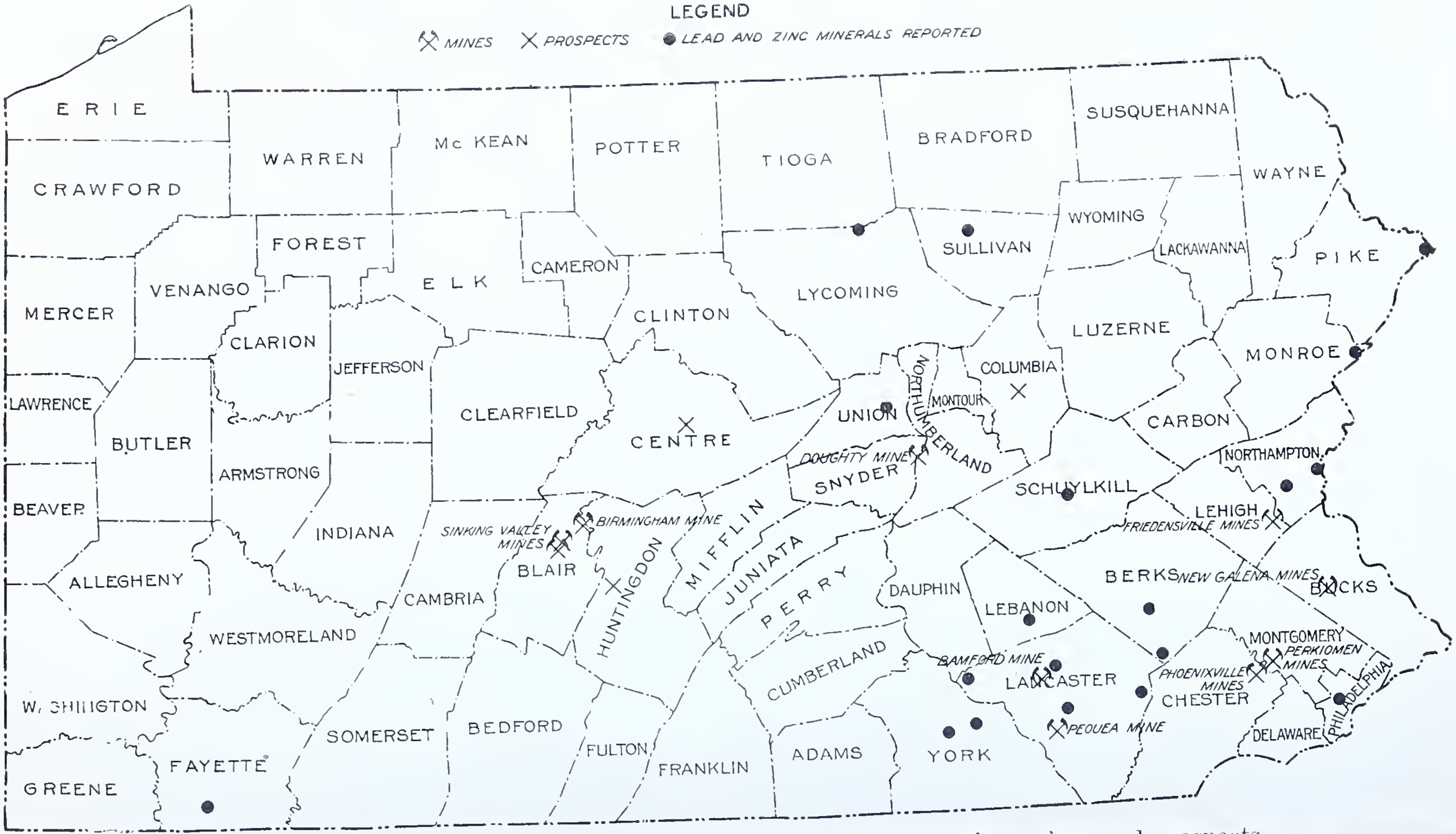

FIGURE 1. Map of Pennsylvania showing location of lead and zinc mines and prospects.

ALLEGHENY COUNTY.

The only known reference to lead or zinc in Allegheny County is the statement of Genth[1] that Prof. Lesley has found a cube of galenite surrounded by clay in argillaceous siderite near Pittsburgh.

BERKS COUNTY.

In his report on Berks County, D'Invilliers[2] mentions the finding of aurichalcite in Jones magnetite mine in Caernarvon Township and galena and aurichalcite at the Fritz Island magnetite mine near Reading.

BLAIR COUNTY.

The lead and zinc deposits of Blair County[3] are confined to Sinking Valley which extends from Little Juniata River in a southwesterly direction about ten miles. Two mountain ridges of sandstone flank the limestone valley on the northwest and southeast, and, uniting just east of Altoona, close the south end of the valley. The limestones of the valley belong to the great Cambro-Ordovician limestone series. The valley is about five miles wide along the Little Juniata but gradually narrows as the bounding ridges come closer together.

Within the limestones of the valley, lead and zinc minerals have been found in many places. Much prospecting seems to indicate that the only localities which might justify the expenditure of money and effort in the search for ore are in the two ends of the valley. These are the only places where mining has been carried on. The chief ore bodies are those about one-fourth mile southwest of Birmingham Station, east of Tyrone. Others are near the end of the valley called the "Kettle" east of Altoona.

History of Mining Operations.

The first lead and zinc mines of Pennsylvania were operated in the Sinking Valley, Blair County, during the Revolutionary War. The Continental Army being in great need of lead for bullets, a party was sent to investigate some lead deposits said to be in the Wilderness near Frankstown. As a result of the examination General Daniel Roberdeau opened and worked some shallow mines in the southern end of Sinking Valley during 1778 and 1779. Several letters from General Roberdeau and others concerning these operations are in the Pennsylvania Archives (First Series) especially in Vols. 6, 7, and 8. At one time 1,000 pounds of lead was sold to the State at $6.00 a pound in the depreciated currency of that period. It is not known when the mines closed but probably the operations were short-lived because of the expense of transporting materials for mining and smelting the ore, the maintenance of the laborers in the Wilderness, as it was called, and the guards that were necessary on account of hostile Indians.

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[1] Genth, F. A., Preliminary report on the mineralogy of Pennsylvania: Pennsylvania Second Geol. Survey, Rept. B, p. 11, 1875.

[2] D'Invilliers, E. V., The geology of the South Mountain belt of Berks County: Pennsylvania Second Geol. Survey, Rept. D3, vol. 2, pt. I, pp. 394, 397, 1883.

[3] Platt, Franklin, Zinc and lead deposits of the Sinking Valley: Pennsylvania Second Geol. Survey, Rept. T, pp. 247-277, 1881.

The next period of active mining was in 1795 when John Musser was employed by Robert Morris to drive a drainage tunnel into the side of the hill near Birmingham to connect with a shaft previously sunk. No further information is available concerning this undertaking.

It seems that there was little if any more work done until 1864 when the Keystone Zinc Company was organized and with abundant capital started operations on a large scale. Most of the work was done in the northern part of the valley near Birmingham but investigations by this company and others were made in a number of places in the southern part of the valley. New shafts and tunnels were driven and a large reducing plant for the manufacture of zinc oxide was built near Birmingham for the treatment of ores from this and other regions. In this attempt the principal attention was given to zinc while in the previous operations only lead was sought and the zinc minerals present were regarded as worthless or as part of the gangue. After six years, during which several thousand tons of ore were mined, the company became financially involved and the plant was closed in 1870. Since that time there have been sporadic efforts to discover workable ore beds in various parts of the valley but with indifferent success. In 1875 some diamond drill boring was done in the southern part of the valley and in 1876 a small quantity of ore from another property was mined and shipped to the Bamford reduction plant near Lancaster.

The latest known attempt to reopen the mines was in 1901 when a certain company issued a prospectus and endeavored to interest capital in the project. This is said to have been merely a stock-selling scheme.

At present the mines are in bad condition although the writer was able to go down one of the old shafts near Birmingham in the summer of 1921 and to see something of the old drifts and stopes that are above water level.

Occurrence and Character of the Ore.

The dolomitic limestone strata of Sinking Valley form a slightly overturned anticlinal fold that extends throughout the valley with the axis pitching to the southwest. The close folding has shattered the rocks and mineral-bearing solutions have deposited the lead and zinc ores in the crevices.

In the Birmingham region where a number of shafts were sunk and an adit driven 347 feet into the side of the hill only one important vein seems to have been encountered, although there were many cross veins and off-shoots. This vein seemed to parallel the strike of the enclosing limestone strata, about N. 65° E., and was near the crest of the anticlinal fold. Slickensides were observed on the ore and the wall rocks, showing movement subsequent to the deposition of the ore. One drift 167 feet long followed a vein said to have averaged somewhat more than seven feet in thickness. No statement is given as to the relative proportions of gangue and ore minerals.

In the south end of the valley the veins cut across the strata. Many were prospected over a considerable area but it is said that few were more than six inches wide, although one was found with a width of 14 inches. Again no data concerning the constitution of the veins are available.

The ores consisted primarily of sphalerite and galena with dolomite, barite, pyrite, and "no inconsiderable amount of brown, highly ferruginous, argillaceous matter." In the Birmingham region the zinc ore predominated whereas the ores near the "Kettle" contained more lead; in some cases the lead content exceeded that of zinc. Smithsonite, calamine and cerussite were found in the upper levels.

Platt[4] gives the following analyses of ore from the Birmingham shafts.

Analyses of zinc ore from Birmingham, Blair County, Penna.

Silica	4.53	9.67	9.67	6.90
Carbonic acid	27.80	29.80	19.03	28.69
Oxide of cadmium	1.84			
Oxide of zinc	46.95	34.50	31.10	47.50
Lime	2.48	11.08	1.17	2.17
Sulphur	.74	.12	.25	.18
Lead	5.44	.82	1.09	1.20
Iron, magnesia and water	10.22	14.01	37.69	13.36
	100.00	100.00	100.00	100.00

Another writer[5] states that "the ore of Sinking Valley, Pennsylvania, treated at the Keystone Works, contained, commonly, 6 to 8 per cent galenite and gave an oxide with 25.084 per cent sulphate, 73.246 zinc oxide, and 0.574 zinc sulphate."

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[4] Platt. Franklin: op. cit.

[5] Williams, Charles P: Trans. Amer. Inst. Mining Eng., vol. V, p 425, 1877.

Production.

Platt says that more than 2000 tons of ore were mined by the Keystone Company. This probably represents the greater part of all the ore that has been obtained from all the workings in Sinking Valley.

Future Prospects.

The present inaccessibility of the old mines prevents forming definite conclusions concerning the nature and extent of the remaining ore bodies. When the mines were closed in 1870 the prevailing opinion seemed to be that the best of the ores were exhausted. In view of the fact that extensive prospecting had been done in many places both by sinking shafts and by diamond drilling it does not seem probable that the district possesses much merit as a lead or zinc producer.

BRADFORD COUNTY.

Genth[6] states that minute quantities of galena associated with pyrite occur occasionally in the Carboniferous sandstones of Bradford County.

BUCKS COUNTY.

In Bucks County, lead and zinc minerals have been found in the Triassic shales over a considerable area west and northwest of Doylestown, which is 25 miles north of Philadelphia. Considerable mining has been done in the vicinity of New Galena on the North Branch of Neshaminy Creek, three miles northwest of Doylestown.

History of Mining Operations.

It has not been possible to secure a satisfactory history of the New Galena mine as there is much disagreement in statements. The following account, based on newspaper articles, a report by John Annear, who styles himself a "practical metallic miner," and recollections of present residents of the region, is offered with some misgivings although, in the main, it is probably correct. Some of the information emanated from persons who were interested in having favorable reports of the mine circulated and these circumstances may have colored their statements, making them unduly optimistic.

The story is told that when Washington's army was stationed at Valley Forge some lead for bullets was obtained from these deposits but the writer has failed to find any verification of this report and is not inclined to accept it.

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[6] Genth, F. A., op. cit. p. 11.

It is said that prior to 1856, residents of the region in digging wells occasionally found pieces of a hard, black material which was supposed to be coal but would not burn. A piece washed from the embankment of a mill race in 1856 was tested and found to be galena. The following year two Doylestown men dug out about thirty pounds of the ore but did no further prospecting. In 1860 two men in digging post holes encountered a large block of lead ore which excited their curiosity because of its weight and the sparkling appearance of a freshly broken surface. They are said to have crudely smelted it in a neighboring blacksmith shop and obtained lead. The story caused some excitement in the neighborhood and shortly after a Mr. Dickinson from Philadelphia visited the locality and secured an option on the Wetherill property where the ore had been discovered. Failing to find ore in paying quantities he surrendered the property.

On April 1, 1861, Jacob and George Neimeyer bought the property for $21,000 and began an active search for ore. They found several veins but unfortunately encountered so much water that they could not continue to work the mine profitably. They engaged John Annear to make a report on the property and to assist them in finding a buyer. The following statements are abstracted from this report.

> The mining operations consist principally of a large "Gauphin" or longitudinal opening on the course of one of the veins, extending from the cross road 256 feet northeast, and varying in depth from twenty to fourty-four feet from the surface. The south-western breast and along the bottom from that point, to within a few feet of the engine shaft, the Lode averages about two feet in width, rich in Lead, with some Sulphuret of Zinc, and rich specimens of red and black Oxide of Copper, which, if wrought on regular mining principles, would yield a handsome profit.
>
> In the Engine Shaft, which is being sunk some twenty feet, east of the Lode, to intersect it lower down, there is a branch of very rich Galena, four inches wide, evidently a "Dropper," and will doubtless enrich the Lode at the point of intersection. In the immediate vicinity of this shaft, the Lode is disordered by a "Slide," which passes through it at this place. About fifty-three feet northwest of the shaft, the Lode has been followed down to the depth of fourty-four feet, (the water being kept out by a three inch branch pump.) The length of this working is about seventy feet on the course of the Lode, and the bottom of which is *under* the "Slide." This part of the Mine presents the richest course of ore yet discovered on the property. For about thirty-five feet in length, the Lode is three feet wide, very rich in hard, compact Galena, with every appearance of lengthening in going down. At this point a crosscut is commenced to intersect the "Dickeson Vein," which appears to run parallel at a distance of about thirty-five feet, which is reported to be eighteen inches wide, of good Galena, at the bottom of the shaft, sunk by Professor M. W. Dickeson, to the depth of thirty-eight feet from the surface, near the cross road.
>
> The Lode on which the present proprietors, Messrs. J. and G. Neimeyer are working, runs nearly north-east by south-west, and has been opened at places almost the entire length of their property. At the distance of 453 feet southwest of the main working, a trial shaft has been sunk on the Lode, where it is two feet wide, of rich ore. This shaft is being cleaned out for further operations.

The Lode where opened has regularly defined "walls," and underlies east about two feet in the fathom, when "Gangue" appears. It is composed chiefly of Quartz, Calcareous Spar, with Conglomerate, containing Shales, etc. The surrounding strata are composed of various colored slates and shales, interlaced with strings of Quartz, most of which contain more or less of Galena, showing it to be a highly metalliferous channel of ground. The strata at the west, or "Foot Wall" of the Lode, does not differ much in character from that at a distance from it: but on the east or "Hanging Wall" it is of a much softer and kindlier nature, being of a light buff color, resembling the white killas of Cornwall, and easily wrought with pick and gad, being wide enough for "Rescuing" the Lode, materially diminishing the expense of mining. The three other Lodes, as far as I could Judge, seemed to exhibit the same characteristics, and will no doubt prove good courses of ore when explored.

Messrs. J. & G. Neimeyer have already shipped to market and sold one hundred and six tons of ore, yielding seventy-five per cent. of Lead, and eleven ounces of Silver, to the ton. They have now at the surface in various stages of preparation for the furnace, as near as can be estimated, eighty tons of similar quality, and are daily adding to that amount.

Knowing nothing of the trustworthiness and professional ability of Mr. Annear one cannot determine whether the favorable report was based on facts or was prepared for the purpose of effecting a sale. It evidently accomplished the latter purpose as the property seems to have been sold by the Neimeyers to a New York company for $75,000. This company apparently did little work other than to sell considerable stock, said to have amounted to $105,000.

General statements to the effect that the mine was operated after this, especially in 1888 and 1891, are vague and reports are conflicting. In 1894 a man named Cowan started work at the mine but evidently accomplished little. In 1904 some prospecting was started on a nearby farm. In fact a great deal of prospecting has been done throughout the region and although galena and sphalerite have been found the results have not been encouraging except in the one locality along the North Branch of Neshaminy Creek.

In 1921 the Guerden Glen Lead Mining Co. acquired the property but, up to March 1924, had done no regular mining, only surface development, working over the old dumps. The company proposes to unwater the mine and determine how much if any ore remains in the underground workings. Considerable unproductive expense must be incurred for reopening the mine before any ore can be raised.

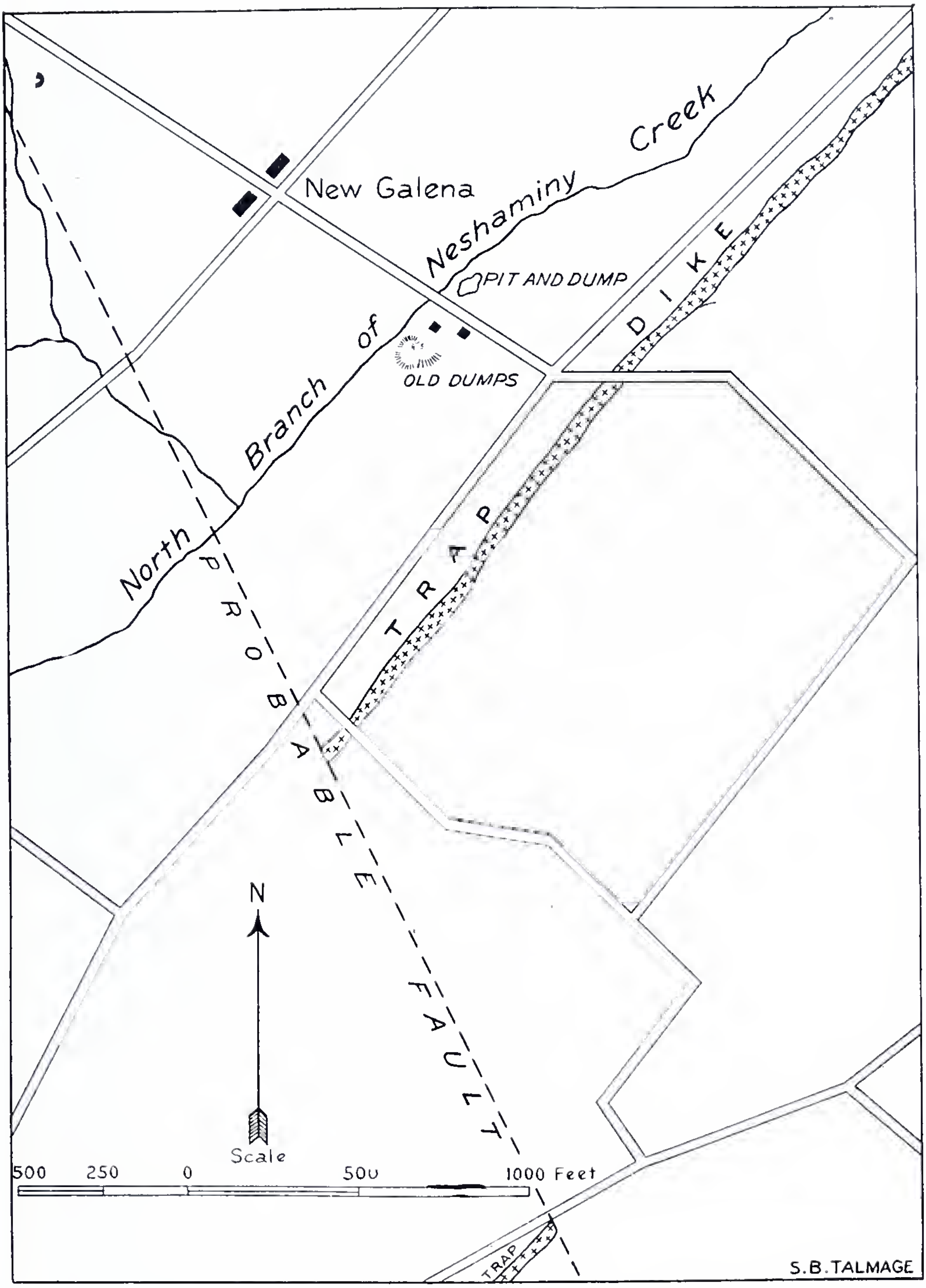

FIGURE 2. Map showing location of New Galena mine dumps and relation to trap dike and fault.

Occurrence and Character of the Ore.

The country rock of the region consists of dark colored Triassic shales that have been intruded by igneous dikes or sills of diabase, commonly called "trap rock." A sill is exposed in the vicinity of the mine and from specimens on the old dumps, as well as from hearsay information, the underground workings cut through some diabase. One statement is to the effect that the ore lies under a sheet of the igneous rock.

The ore seems to be confined to shattered zones that probably have a rather definite trend, according to all descriptions available. Within the zone of fractured rock the ore occurs as small veins filling former open fissures, as the cementing material in brecciated shale, and as disseminations and probable replacements of the shale. The galena and sphalerite are associated with much quartz, and numerous small cavities are lined with druses of fine quartz crystals. The rock containing the ore minerals is either black or gray shale. The gray material closely resembles limestone in general appearance and seems to have been mistaken for limestone.

Some unusually fine specimens of galena and sphalerite ore have come from the New Galena mines. According to report a block of ore weighing 1,000 pounds was once found.

The following minerals have been reported from the mines: quartz, dolomite, ankerite, calcite, galena, sphalerite, pyrite, chalcopyrite, and bornite. Some of the galena has yielded 10 to 15 ounces of silver and 10 cents in gold per ton.

Conclusion.

So scanty is the available information regarding the operations, the thickness, number, and extent of the lodes, the character of the ore in the lodes and their richness, and many statements have been so conflicting and highly incredible that one is forced to be careful in either praising or condemning the property. Handling the water with improved pumps would not be as serious a matter as it was sixty years ago, and if there is the showing of ore underground that has been claimed it may be possible to operate a mine successfully. The writer would be inclined to encourage the judicious expenditure of a moderate sum of money under expert supervision to determine the real character of the ore bodies, but such expenditure should be regarded as a hazardous venture.

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Daily Democrat, Doylestown, Pa., June 6 and July 5, 1921.

Doylestown Daily Intelligencer, June 6, 1921.

CENTRE COUNTY.

In 1915 an exploration tunnel was driven into the hill just north of Bellefonte in search of lead and zinc ores. Some fair specimens of galena and sphalerite filling small crevices in the Tuscarora (formerly known as the Medina) sandstone were found but not in paying quantities.

In the same horizon in the Shawangunk Mountains of southeastern New York, only a few miles from Port Jervis and the Pennsylvania line, several lead and zinc mines were worked between 1820 and 1870 and have been prospected several times since.[7] "The ores occur in fissures, brecciated zones, and along the bedding planes of the grit." One of the mines is said to have yielded 10,000 tons of ore between 1863 and 1870.

It seems unlikely that any deposits of equal importance will be found in this horizon in Pennsylvania although the occasional finding of lead and zinc minerals in these sandstones is to be expected.

CHESTER COUNTY.

Location of Mines.

All the lead and zinc mines in Chester and Montgomery counties are near Phoenixville, which is 25 miles west of Philadelphia on Schuylkill River. Most of the mines are two miles south of Phoenixville near Pickering Creek; two mines are four miles east of Phoenixville between Perkiomen Creek, Mine Run, and Audubon (formerly Shannonville), in Montgomery County. The map on page 23 shows the location of the mines.

With the exception of a little sporadic development very recently, no mining has been done here in 50 years. The underground workings are inaccessible and there are no places where the lodes can be seen at the surface.

History of Mining Operations.

Lead mining in this district began about 1808 and there is definite information that "The Perkiomen Mining Company" was mining lead ore in 1809. Ore was first discovered along Mine Run, one-half mile northwest of the present village of Audubon and an 80-foot shaft was sunk. The company drifted 56 feet along the vein and drove a drainage tunnel 356 feet from the bottom of the shaft to its outlet near the creek. Considerable ore was found but owing to misunderstandings among individuals the works were abandoned in 1810.

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[7] Newland, D. H., Mineral Resources of the State of New York: New York State Museum Bull. No. 233-234, pp. 300-306, 1921.

Soon afterward the mine was purchased by Samuel Wetherill and work resumed. In 1826 it was stated that from that time "the works have been pretty regularly conducted." The shaft was sunk to 160 feet and drifts run off at 70, 115, and 150 feet. Considerable stoping was done.

There is a break in the record of mining between 1826 and 1851, but we learn that when in 1835-36 standard weights and measures of American metals were ordered by Congress for the U. S. Treasury the zinc used was obtained from a mixture of the Perkiomen and Franklin Furnace, N. J. ores. This seems to have been the first utilization of American zinc ores. Up to that time lead and zinc ores had been worked solely for the lead content.

On February 15, 1851 a charter was granted The Perkiomen Consolidated Mining Co. The company organized "for the purpose of mining, selling, or smelting copper and lead ores, and erecting the necessary buildings and machinery for such purposes, and as such shall have power to lease or purchase the Perkiomen and Ecton mines, and certain other mines and mining lands, and all other estates of what kind soever, real, personal or mixed, situated in the counties of Montgomery and Chester." The company was capitalized for $300,000. On March 19, 1851, the capital stock had been subscribed and a meeting of the stockholders was held in Philadelphia.

About this time or perhaps a little earlier, lead and zinc ores were discovered along Pickering Creek, south of Phoenixville. In 1850, the General Assembly passed acts of incorporation for the Chester County Mining Co., and for the Montgomery County Mining Co. The Wheatley Mining Co. was also incorporated about the same time, for it started mining operations early in 1851.

Between 1851 and 1855 lead and zinc mining was actively carried on by a number of different companies in the two mining districts of Montgomery and Chester counties. From 1855 to 1865 and perhaps a few years later some work was done on different properties at intervals. During the most active period more than a dozen separate and distinct lodes were prospected and considerable work was done on most of them. The lode most extensively worked was the Wheatley. Three companies, the Wheatley, Brookdale, and Phoenix operated on this lode but in 1855 consolidated under the name of the Pennsylvania Lead Co.

A later consolidation was effected about 1864 in which the New York and Boston Silver Lead Co. acquired the Wheatley, Brookdale, Charlestown, Morris, and perhaps other properties. Considerable

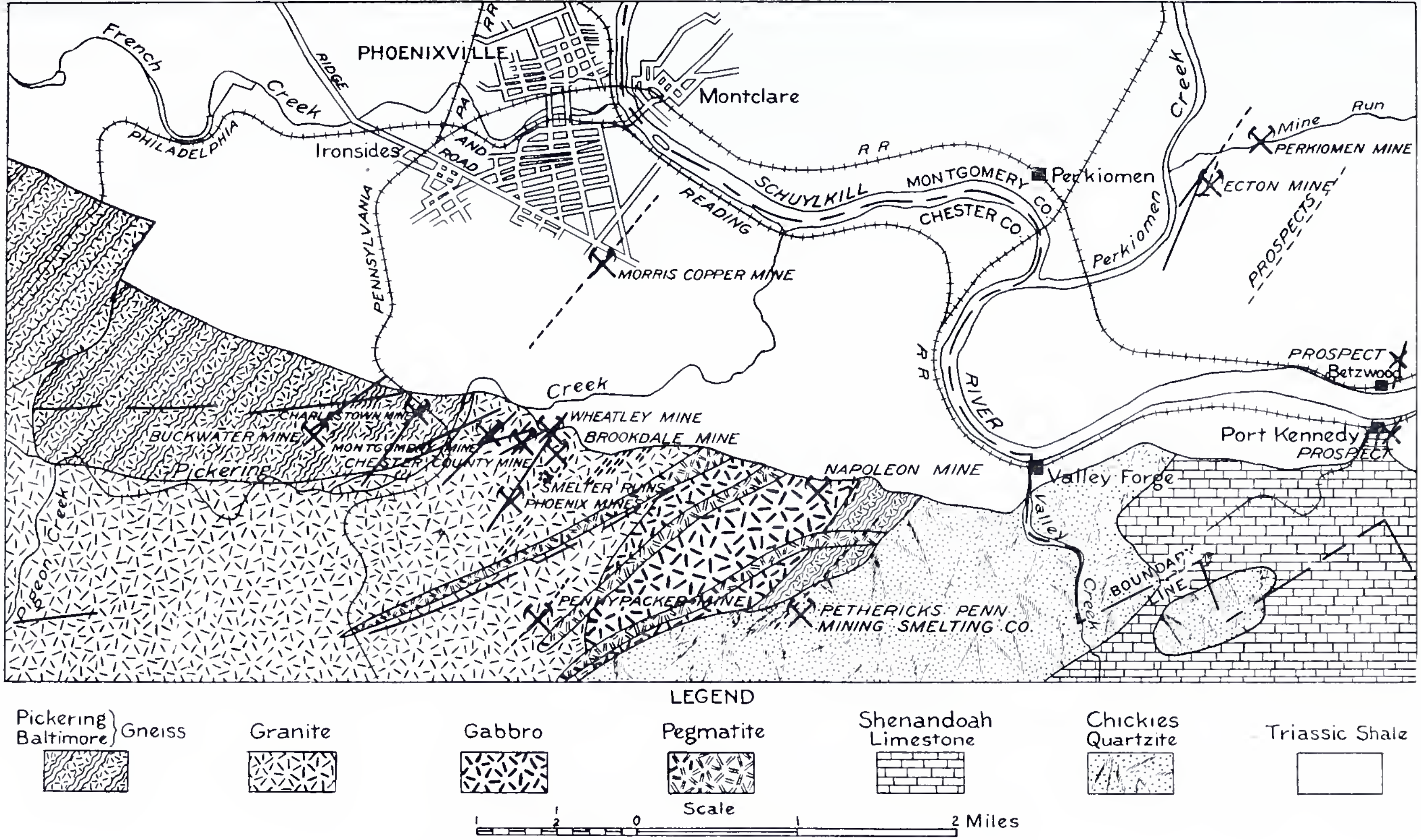

FIGURE 3. Map of Phoenixville mining district.

work was done in 1864 and 1865 in reopening the Wheatley and Brookdale mines. The date when work stopped is not known, but it is believed that all lead and zinc mining in both Montgomery and Chester counties had been abandoned before 1870.

In 1918 the Eastern Mining and Milling Co. leased the property on which the Chester County lode is located, and dewatered and retimbered part of the old workings. Some stoping and additional drifting was done and a small mill was built. Work was continued for about two years and some high grade ore was shipped.

The Pennsylvania Lead and Zinc Co. and the Great Eastern Mining and Manufacturing Co. in 1923 were trying to raise money for reopening some of these old mines.

Geological Occurrence of the Ore.

For many years there has been no opportunity for studying the underground geology except in the Chester County lode, consequently descriptions of the geological character of the lodes and associated country rocks must be based on reports prepared during the time of their active exploitation. For that reason the report of H. D. Rogers in his "Geology of Pennsylvania," the principal source of information, is extensively quoted here. At present it would not be possible to accurately locate some of the lodes. Accordingly, in the accompanying geological map representing the recent mapping by geologists of the U. S. Geological Survey, the lodes shown on Rogers' map are indicated. An inspection of this new map shows that all the lodes of the Triassic are contained within the Stockton formation, whereas the lodes of the gneiss are present in areas mapped as both sedimentary and igneous gneisses, The Charlestown and Buckwater lodes lie within the area of Pickering graphitic gneiss, an altered sedimentary formation which contains workable beds of graphite a few miles westward. The Montgomery, Chester County, Wheatley-Brookdale, Pennypacker, and a few unimportant unnamed lodes are in granite (monzonite and granodiorite). The Napoleon and Pethericks Penn Mining Smelting Co. lodes are included in the Baltimore gneiss.

Rogers made the following report on the district in 1853 and in his "Geology of Pennsylvania"[8] issued in 1858 republished the article with only slight modifications.

Geological Relations of Mineral Veins.

It will be seen, upon consulting the map of the mining district of Montgomery and Chester counties, that the metalliferous lodes or veins extending from the Perkiomen Mines in Montgomery County to the Charlestown Mines in Chester County, occur not far from the boundary which separates the gneissic rocks of this region from the Middle Secondary formation of red shale and sandstone. Some of them would seem to lie entirely in the one set of strata, and some of them in the other; while others again, especially the interesting group of the Pickering Creek Veins—on the economical prospects of which I propose to venture some opinions—are partly within the gneiss and partly within the red shale, penetrating the latter, however, to apparently a trivial extent. It would seem to be a pretty general fact, that such of these veins as are confined entirely or chiefly to the gneiss bear *lead* as their principal metal, whereas those which are included solely within the red shale are characterized by containing the ores of *copper*. But the *zinc* ores, viz., zinc-blende and calamine, prevail in greater or less proportions in both sets of veins, existing, perhaps, in a rather larger relative amount in the copper-bearing lodes of the red shale. Thus the Perkiomen and Ecton Lode, the United Mine Lode, the Shannonville South Lode, a small lode on French Creek, a lode at Port Kennedy, and the Morris Lode near Phoenixville, are genuine *copper veins*, and they are all, without exception, in the Red-shale formation.

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[8] Rogers, H. D., Geology of Pennsylvania, vol. II, pp. 699-705, 1858.

On the other hand, the Wheatley and Brookdale Lode, the Chester County Lode, the Montgomery Lode, and the Charlestown Lode, with other adjoining ones of the same group at present more imperfectly developed, all lying within the gneissic rocks, or if extending into the Red shale not explored beyond its mere margin, are equally genuine *lead* veins. This interesting general fact is not presented, however, as an invariable law, unattended by exceptions, for it must be observed that several of the lead veins of the gneiss actually enter the red shale; two of them, the Wheatley and the Chester County Lodes, carrying their ores of lead and the usually accompanying vein-stones into this rock, while some of the others enumerated are traceable still farther within its boundary by their characteristic surface-fragments. Nevertheless, in all these cases the red-shale formation which they penetrate is a very thin and superficial capping, or unconformable covering to the gneissic strata, within which, even here, the chief body of the veins must be contained below this shallow depth. Thus, even in these instances, the exceptions to the rule are more apparent than real. But partial deviations from the law, of another sort, are met with; some of the lead veins of the gneissic strata contain traces more or less abundant of the ores of copper, and, more strikingly, very considerable proportions of lead ore are occasionally associated with the copper ores, in the copper veins of the red shale, especially in the lodes of the Ecton and the United mines. Yet even in these last-mentioned instances, which are the most conspicuous exceptions to the general rule hitherto brought to light in the district, the proportions of lead ore to copper ore are quite subordinate, when estimated for each entire lode.

The *gneissic strata* of the tract embracing this group of lead-bearing veins seem to differ in no essential features from the rest of the formation ranging E. and W. through this belt of country. Here, as elsewhere, they consist chiefly of soft, thinly-bedded micaceous gneiss, a more dense and ferruginous hornblendic gneiss, and a thicker-bedded granitic gneiss, composed not unfrequently of little else than the two minerals, quartz and felspar.

A soft, white, and partially-decomposed granite is a very frequent associate of the stronger lead-bearing veins, particularly in their more productive portions; but this material belongs, in all probability, not to the ancient granitic injections of the gneiss, but to those much later metalliferous intrusions which filled long parallel rents in that formation with the lead ores and their associated minerals. It appears to be, in fact, of the same date of origin with these metalliferous lodes, and may be viewed as derived in part or altogether from the fusion of the intersected gneiss, by the intensely hot mineral matter of the vein brought into close contact with the walls of the fissure. The melted constituents of the gneiss have thus floated up along the sides of the true vein, and re-crystallized, upon cooling, in chief abundance upon the exterior of the lode. Soft granitic matter of this sort very frequently adjoins the hanging walls of the less steeply pitching lodes of magnetic iron-ore in New Jersey and New York; and it would naturally tend to place itself in this position, from its superior lightness compared with the metallic matters.

The gnessic strata and their granitic injections throughout this district, display a softened, partially decomposed condition, extending in many places to a depth of several fathoms. This rotted state does not, however, pervade these materials to as great a depth as it does in the belt of gneiss lying S. of the Chester County Valley and nearer the level of the tide. To its influence we must impute the fertility of the soils resting on the formation, and the soft lines of the landscape. Its origin is due, in part, at least, I think, to the action of the sea-water, which once evidently rested over all this S. edge of the low Atlantic slope of the country, dissolving by chemical forces the more soluble ingredients of the felspar, hornblende, and mica.

Immediately adjoining some of the mineral veins at the Wheatley and Chester County lodes, the gneiss is softened and decomposed to a very considerable depth, and, in some places, in a very thorough manner; the more micaceous beds being converted into a crumbling, purplish-red, unctuous, and clayey material, easily crushed in the hand, though taken from a depth of many fathoms. This condition, which has much facilitated the cutting of the upper adits of these lodes, is the result, in all probability, of a chemical influence exerted on the materials of the strata by some of the elements which belong to the veins, or which passed up through the fissures they fill at the time of their injection. Highly-heated steam and other volcanic vapours have manifestedly been the agents of many of the changes we witness in the walls of our igneous veins. At the same time, it must be borne in mind that, near the surface, the penetration of external water and its carbonic acid, and free oxygen along the sides of the lodes, may have assisted this decomposition; and there can be no doubt that these elements, thus introduced, by leading to chemical changes and replacements in the constituents of the lodes, have caused the formation of several of the minerals we find—the carbonates and sulphates, for example, which are usually met with in the cavities and nests of the veins.

The dip of the gneiss throughout this district is generally about S. 20°E., and seldom at any high angle, the most common being 30°-40°; but this direction and inclination are, in some cases, much affected by contact with the veins. These *cut* or intersect the beds of the gneiss, both in strike and in dip, even where they seem, by the violence of the disruption at the formation of the vein, to have twisted the strata from their ordinary bearings. This intersection or cutting shows these to be true lodes.

Of the *general relations of the mineral veins* of the district to each other, enough is already known to convince us that these lodes are physically associated as members of one natural group of igneous injections, indicating that this is a genuine mineral region and that the distribution of its metallic wealth is controlled by definite and ascertainable laws.

Of the one dozen or more lead and copper lodes of greater or less size brought to light in this quite limited region of five or six miles length, and two or three miles breadth, the greater number are remarkably similar in their course, ranging N.32°-35°E., and S.32°-35°W.; and what is equally worthy of note, they dip, with scarcely an exception, towards the same quarter or S.E., though in some instances so steeply as to approach the perpendicular. Those which do not observe this direction, seem, as far as traced, to range N.52°-54°E. and S.53°-54°W., and by their mutual parallelism to each other, to constitute, as it were, a second subordinate group or system of veins. There are one or two other lodes, such as the *counter lode* of the United mine, which range at even a less angle to the meridian than the first or principal set, namely, about N.26°E.

The point of chief interest is the wonderfully close parallelism of the more numerous group embracing the larger and more promising veins of the district.

There is no marked difference in the general character of the vein-stones of the several mineral lodes, nor any feature to distinguish as a class those of the red shale from those of the gneiss, nor, again, those observing the normal direction of N.34°E. from those of the more exceptional direction of N.53°E. Yet each vein possesses certain special subordinate characteristics in both its non-metallic minerals and its ores, and even in its surface vein-stones and gossans, by which the initiated observer may recognize its individuality.

The predominant material in all these lodes is quartz, then sulphuret of iron; next to this, perhaps, the sulphate of baryta, though this is a much more variable ingredient, being scarcely seen in the Wheatley and Chester County veins, while in others, as in the Charlestown, Morris, and the United mines, it is in great abundance; besides, these, there occur frequently the materials of the walls of the veins, but in a more or less altered condition; such are the soft, white felspathic granites in some of the lead-veins, conspicuous, for example, in parts of the Wheatley Mine, and the altered shale and sandstone fragments involved with the ore in the Morris Lode. These veins are recognised and traced on their "backs" or outcrops by fragments of indestructible vein-stones, chiefly cellular quartz and sulphate of baryta, and by their gossans, or masses of pulverulent oxide of iron and ochreous earth, interlaced with quartz, or filling cavities in the lumps of this mineral, and still more definitely by the presence of the metallic ores, sometimes well preserved in the cavities, or in the body of these fragments, or oftener only in stains and surface-coatings of the phosphate of lead or the carbonate of copper.

The different lodes differ more, perhaps, in the amount and distinctness of the gossan which they show on their backs and in their higher levels, than in almost any other particulars. In this excellent indication of a good and remunerative metalliferous vein—an abundance of soft brown gossan—perhaps none of the lodes of the region will compare with that of the Wheatley Mine. This material, the product evidently of the decomposition of the sulphuret of iron of the vein, often contains, in this Wheatley Lode, especially at some depth below the surface, a very appreciable trace of silver, derived, most probably, from the decomposition of argentiferous galena, which is one of the characteristic ores of the vein. Sundry assays of its gossans show an average proportion of about ten ounces of silver to a ton of the material.

Mineralogical Character of the Ore.

The Phoenixville mines have long been known to mineralogists for the variety, perfection and beauty of mineral specimens found there. Even yet the old mine dumps are frequently visited by mineral hunters who are usually successful in finding some interesting specimens. The following minerals have been reported from the mines.

Lead Minerals

Common
- Galena
- Pyromorphite
- Anglesite
- Cerussite

Rare
- Wulfenite
- Descloizite
- Mimetite
- Vanadinite
- Stolzite
- Mendipite?

Zinc Minerals

Common
- Sphalerite
- Calamine

Rare
- Smithsonite?
- Hydrozincite

Copper Minerals

Common
- Chalcopyrite
  (some auriferous)
- Chalcocite
- Cuprite
- Malachite
- Azurite

Rare
- Covellite
- Native Copper
- Melaconite
- Pseudomalachite
- Erythnite
- Chalcanthite
- Bornite
- Chrysocolla
- Libethenite

Other Minerals

Common
- Quartz
- Calcite
- Aragonite
- Dolomite
- Ankerite
- Barite
- Pyrite
- Limonite
- Goethite
- Fluorite

Rare
- Gersdorffite
- Bournonite
- Hematite
- Native Silver
- Sulphur
- Amethyst
- Chalcedony
- Greenockite
- Arsenopyrite
- Dioptase?
- Marcasite?
- Millerite?

Galena, pyromorphite, and sphalerite are the only minerals of economic importance in all the mines worked for lead and zinc. Chalcopyrite is the only mineral present in commercial quantities in the mines worked for copper.

J. Lawrence Smith[9] in a description of the minerals of the Wheatley mine gives the following account of the occurrence of the minerals with depth.

> ......In opening the vein and descending from the surface for the first thirty feet, the phosphate of lead was very abundant with some galena and carbonate; a little lower down the phosphate was less, and the carbonate more abundant. Wulfenite and anglesite began to appear at 120 feet, the phosphate and carbonate still continued with the galena with fine large crystals of anglesite and considerable wulfenite; at 180 feet, phosphate very much diminished, carbonate and sulphate in fine crystals; arsenate was found here; at 240 feet, blende, calamine and fluor spar appear with considerable dolomite and but little phosphate of lead, galena forming almost the whole lead ore, anglesite is found, but in smaller crystals.

This variation in the character of the ores shows that there has been considerable leaching of the lead and zinc minerals in the upper levels and enrichment at lower levels. The thickness of the enriched zone has not been determined and it is not known whether the deepest workings were still in the enriched zone or in the underlying primary unenriched portion of the lodes.

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[9] Smith, J. L., Amer. Jour. of Science, vol. 20, Second Series, p. 253, 1855.

One of the most interesting features of these mines in comparison with other lead and zinc mines was the great abundance of pyromorphite. It was the principal ore mineral found in the upper levels. For a time it caused considerable difficulty in smelting but later this was overcome.

In the deeper levels the galena and sphalerite were about equally abundant. Within the vein certain streaks or pockets contained only galena, others only sphalerite, and many others intimate mixtures of the two. Both minerals are coarse grained and owing to perfect cleavage are very brittle and readily broken.

The galena is argentiferous, the amount of silver in it ranging up to 120 ounces to the ton. According to certain writers the galena averaged from 11 to 16 ounces of silver to the ton but others estimated it to average from 26 to 30 ounces.

The lodes range in width up to 5 feet with an average of about 2½ feet. In most places the major part of the lode is composed of gangue material consisting of quartz, decomposed rock constituting clay or gouge, with small quantities of the other minerals listed above. In some places the veins contained practically no ore minerals but on the other hand a thickness of 4 feet of solid galena was encountered in one place in the Brookdale mine.

A description of the Wheatley mine by William P. Blake[10] states that the mining operations have sufficiently developed the character of the vein to show beyond a doubt that the ore is distributed in elongated patches or *shoots* along the vein, having a *vertical rather than horizontal extension,* and lying *parallel with each other.* They are also found to dip, not only with the vein, but obliquely upon it, plunging towards the west at an angle of 45°. These shoots vary in size from a few inches to four or five feet in transverse section, while their length from above downwards is much greater.

The distribution of the minerals in the shoots is also an interesting point. Captain Cockin has observed that in passing through a shoot, *blende* is most abundant on each side, while the central portion is occupied by galena and lead salts.

The following section across Chester County lode, measured by the writer, shows the same characteristics.

Section of Chester County lode.

	Inches
Footwall, slickensided gneiss	
Thin streak of galena in shattered quartz	2
Barren impure quartz	1
Streak of sphalerite in quartz	1

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[10] Blake, Wm. P., The Wheatley silver lead mines: Min. Mag. and Jour. of Geology, Second series vol. 1, pp. 411-418, 1860.

Shattered quartz and decomposed rock with nests of white quartz and small bunches of galena	31
Streak of galena and quartz with some clay gouge	3 to 6
Open fissure, walls lined with quartz crystals with occasional crystals of galena	2
Hanging wall.	

The variation in the width of the vein and the distribution of the ore minerals within the vein make it difficult to estimate the average yield of the lodes. Rogers states that at one place in the Wheatley mine he estimated the lode to yield 1¼ to 1½ tons of good ore per square fathom and in another place 3 tons. But there are other places where the yield might be only a few pounds per square fathom. According to Blake[11] there were more than 4,000 feet of drifts along the lode in the Wheatley mine and the amount of ore raised was 1,800 tons, most of which yielded 60 per cent of lead and an average of 26 to 30 ounces of silver to the ton. We know that considerable stoping was done and this is probably not included in the 4,000 feet of drifts. It is probable that the bulk of the ore came from stopes some of which are described by Rogers as having been carried up to a height of 30 to 55 feet. It would therefore seem probable that the average yield of the lode per square fathom was very low. It must be recognized, however, that at that time little attention was given to the zinc ores as only lead and silver possessed value, and that the total yield of lead, silver, and zinc of the lodes would be somewhat greater.

Although of no economic importance, the orbicular structure of the ankerite, quartz, and galena observed in the ore at various places is an interesting feature of these lodes.

Origin of the Ore.

The lead, zinc, and copper lodes of Chester and Montgomery counties are of hydrothermal origin. They have been formed by deposition from heated solutions probably given off from some deep-seated igneous masses. They are fissure veins and may follow faults wholly or in part. In the Chester County lode the footwall is prominently slickensided and in places the hanging wall also shows slickensides. In the Wheatley mine the vein cuts three trap dikes that have been displaced several feet. On the mine dumps one also finds occasional pieces of slickensided rocks. However, one cannot say whether faulting preceded the deposition of the lodes or not. The shattered character of the gangue and ore minerals and the presence of clay gouge and open, quartz-lined fissures indicate that there has been at least some displacement following the formation of the lodes.

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[11] Blake, Wm. P., op. cit.

The lodes are of Triassic or post-Triassic age as proved by the fact that they cut the Triassic shales of the Stockton formation and the trap dikes that are so commonly found as intrusives of the Triassic rocks of the State.

In every case the lodes have undergone secondary changes through the agency of downward percolating waters. The gossan and cavernous quartz of the outcrops, the secondary minerals such as pyromorphite, cerussite, anglesite, calamine, etc., some of which are found at considerable depths, furnish evidence of the extensive alteration which has taken place.

The abundance of pyromorphite is difficult to explain as there is now no evidence of the source of the phosphoric acid. It is possible that there were some phosphatic beds in the overlying Triassic strata now removed by erosion, but this is only a conjecture.

It seems that Rogers in the passage quoted on preceding pages probably over-emphasized the distinctions between the lodes lying within the gneisses and those found in the shale areas, although he was correct in pointing out general differences. Undoubtedly the shales did have a tendency to cause the deposition of the primary chalcopyrite to a greater degree than did the gneisses and vice versa the gneisses had a selective reaction on the solutions, causing greater deposition of the galena than is found in the veins enclosed by the Triassic shales.

Description of Mines.

Perkiomen mine.—The Perkiomen mine, the oldest of this district, is along Mine Run northwest of Audubon (formerly Shannonville), Montgomery County. For nearly 60 years no work has been done there and at present only the ruins of the old shafts and the extensive mine dumps furnish evidence of the former operations. All descriptions must therefore be taken from old reports.

As stated on a pevious page, mining began here in 1808 or 1809 and continued intermittently for a number of years. In 1851 operations were resumed for a few years, since which time the mine has been idle.

The Perkiomen mine worked a single lode that is entirely within the Triassic shales and sandstones. It trends N. 50°E. and varies in width from 2 to 20 feet as described in detail on later pages. Chalcopyrite is the most abundant ore mineral, with sphalerite, galena, and pyromorphite also present in commercial quantities. The chief gangue mineral is cavernous quartz.

A report by John P. Wetherill[12] read before the Academy of Natural Science of Philadelphia on Dec. 19, 1826 contains the following description of the mine as well as a plate showing a section of the workings.

The shaft has been sunk to a depth of 160 feet from the surface. The Upper drift made by the company, has been extended on both sides to a distance of 192 feet. In addition to this drift, two others have been cut parallel to it, one of them opening 115 feet, and the other 150 feet below the surface; each of them has much the same lateral extent as the upper one, and all three follow the direction of the principal lead vein—that is to say, from N.W. to S.E. The lower and middle drifts communicate by a vertical passage called the Air tunnel.

The Galena was found near the opening of the shaft, in what the miners call a string, or small vein.

The first five feet penetrated the soil mixed with fragments of Red Slate-clay, or red-shell; after which the Sandstone was encountered, occasionally alternating with strata of Slate-clay, for the most part of a dark gray colour.

At the depth of 10 feet, the vein increased to fifteen inches in thickness of solid ore, was regularly formed, and inclining 65°.

At 20 feet the vein continued much the same, though rather poor to the south. Specks of carbonate of copper, and oxide of iron, were now first seen. Inclination 85°.

At 30 feet the rock became harder, and the vein poorer; the gangue for the most part consisting of quartz intermixed with copper, pyrites, and iron.

At 40 feet the vein improved to the north, and had sulphate of Barytes in addition to the former Matrix. Inclination 75°.

At 60 feet the Galena diminished and the salts of lead as the Carbonate and Phosphate, became abundant.

At 70 feet the vein improved, and strings of Blende were discovered; but the water had increased to an inconvenient degree.

The vein now diminished gradually, until at a depth of 82 feet it was considered scarcely worth pursuing in a vertical direction; but the shaft was continued for the purpose of running the drifts.

Accordingly three of these drifts were opened at right angles with the shaft, and penetrated to the extent, and in the direction already mentioned. In the course of these lateral operations, several large rich veins were met with, which yielded the ore in considerable abundance. By way of illustration, it may be remarked that four men were employed for 458 days, during which time the lead they obtained, after being cleaned, washed, and ready for the furnace weighed 1140 cwt.

But a better idea of the veins and their attendant minerals may be obtained by stating the successive products of some one of the drifts; and for this purpose we will take the N.W. course of the Lower drift.

This passage is seventy-two inches high, and forty-two wide. Soon after its commencement, it presents a vein of four feet in thickness, of which the gangue is Quartz and Barytes, with some iron.

The same appearances continue for forty feet, where the vein becomes five feet thick, and has carbonate and phosphate of lead in addition to the former substances.

At 50 feet the vein is three feet across, and is accompanied by sulphuret of zinc.

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[12] Wetherill, J. P., Jour. Acad. Nat. Sci., Phila., vol. 5, pp. 305-316, Phila. 1826.

At 60 feet the vein is five feet through; carbonate of copper and the salts of lead in plenty, with small quantities of carbonate of zinc.

At 70 feet the vein diminished to three feet and a half, but has all the above mentioned minerals.

At 90 feet the vein is but thirty inches wide.

After this drift had been run for 60 feet, a rich vein was observed pursuing a vertical course; the excavation was therefore continued upwards, by which means the middle and lower drifts became united by the Air-tunnel.

The products of the other drifts are in most respects analogous to those of this one.

The ore of this mine yields 75 per cent. of lead, with a trace of silver; but it is to be regretted that it is extremely difficult to smelt by the ordinary modes, and indeed no plan has yet been tried by which it can be reduced with facility. From this cause, the mine is at present inactive; but the proprietor has lately instituted a series of experiments that may eventually obviate the difficulty.

From the above description it will be seen that in 1826 the mine was regarded as a lead mine. When most actively worked in the early 50s, it was considered as a copper mine. We have records of 151 tons of copper ore shipped to England and Baltimore during 1858 and 6½ tons of lead ore sent to the Bay View Smelting Works on Staten Island.

In 1863 the Perkiomen Mining Co. issued a prospectus in their attempt to secure capital to reopen the mine. The following excerpts from this pamphlet may therefore in some particulars be unduly optimistic although doubtless essentially correct.

Mr. Charles P. Williams, who calls himself a "Chemist and Mining Geologist" gives the following descriptions:

Veins of the Property of the Perkiomen Company.

The several veins on the property of the Perkiomen Mining Company are confined entirely to the sandstone. Their main, though not sole metalliferous ingredients, is therefore some of the combinations of copper; a small amount of galena and the oxidized ores of lead occur in them however. They are made up of quartz, sulphate of Baryta or heavy spar, and gossan or ferruginous matter, with yellow copper ore (chalcopyrite, yielding, when pure, 34.5 per cent. of copper) and green carbonate (malachite, yielding about fifty-six per cent. of metal.) disseminated throughout. Quartz is the predominating vein-stone. Zinc blende occurs, at times, in them in very considerable quantities.

The course of the vein upon which the mine has been opened is about 50° east of north and west of south. It, therefore, belongs to the second system or group above indicated, though it differs in no wise, from the other veins in the same formation in the composition and structure of its vein-stuff, consisting, like all the other cupriferous lodes of the district, of quartz, heavy spar and gossan with malachite and copper pyrites. It varies in thickness from two to twenty feet. While it has shown itself in many portions exceedingly rich, the ores appear to be very irregularly disseminated, occurring in heavy bunches and masses rather than being uniformly distributed. The operations thus far conducted in this vein show that the limits of such masses of ore are marked by the occurrence of large deposits of blende.

Yield and Condition of the Vein.

For data from which could safely be deduced the yield per cubic fathom of the Perkiomen Vein, I have searched the published documents of the former Company, and find in the Report of the year ending April 1, 1852, only the following: During that year there had been raised and sold six hundred and eighty tons of ore, ranging in value for refined metal from seven to twenty-three per cent.; according to the table (A) of the ore sold, nineteen per cent. will represent the average yield of this ore. During the same period the amount of ground broken was six hundred and seventy-eight fathoms, giving, from the above, an average of about one ton of ore per cubic fathom, or, at nineteen per cent. three hundred and eighty pounds of ingot copper; an amount sufficiently great to pay all expenses of mining, superintendence, smelting, etc., and leave a very considerable margin for profit. These figures are given on the authority above indicated; nothing more definite can be stated in this report of the yield of this vein, nor are the workings on it now accessible to a depth below the water level that its present appearance may be pronounced upon. I may state, however, that, at the time of former visits when the deeper workings could readily be examined, my impressions of the then value of the lode were of the most favorable character.

In extending the forty fathoms level north-east (on the course of the vein) from the engine shaft, a seam of ore was cut, which rapidly widened towards the lower levels, and which, when intersected by the extension of the fifty fathoms level, was found to be a heavy mass of cupriferous minerals of sixty feet length and eighteen feet width, and still increasing in dimensions toward the sixty fathoms level. If this widening out still continues—and there are no good grounds for anticipating the contrary—then your Company will have by extending the sixty fathoms level but a short distance northeast from the main shaft, a valuable back of highly productive ground which ought to prove handsomely remunerative. By reference to the longitudinal section of the workings, the position of this rich mass of ore can at once be seen.

I am creditably informed that a large amount of ore, which will average in the neighborhood of eight per cent. for pure copper is still remaining in the stopes on the ten and twenty fathoms levels south-west from the engine shaft, which can be at once availed of as soon as the mine is put in fork to that depth. Through carelessness in management this was never removed but left standing as being of too low a percentage. The lode is said to vary in width, in these levels from two to fifteen feet, to be of a very promising character and to abound in good bunches of ore. In the report of the then manager, C. M. Wheatley, Esq., to the Directors of the old Company for the year 1852, it is stated that the vein in the end of the twenty fathoms level "continues orey, and will probably yield from two to three tons of ore per fathom."

A shaft sunk on this Perkiomen vein to the south of the road from Shannonville to the mine exhibited at the time of my recent visit, (July 13th) an exceedingly promising lode. Last year, a party of tributers had commenced a drift south-west from the shaft just above the water level, (say fifty feet from the surface at that point,) and had carried it in some twelve feet. The vein here was forty-two inches in width and carried a considerable amount of galena and copper pyrites. For particulars in reference to the appearance of the vein in all openings, I must refer to the report of Captain Cocking, formerly connected with the works, a gentleman thoroughly acquainted with the ground and whose reputation for probity and skill as a miner need no endorsement from me. His statements confirm what I have above stated and show that your Company will commence operations under very favorable auspices, several other very heavy bunches of ore being available as soon as a force can be got into the mine.

Surface Improvements and Mining Plant.

There are already on the premises an office, blacksmith and material shops, an assay house, a powder magazine and six cottages for miners all comparatively well-preserved and requiring the expenditure of a small amount of money to render them fit for use. Besides these, are two stone engine and boiler houses of the most substantial construction. One of these, in close proximity to the shaft, contains a fifty inch cylinder, low pressure, Cornish beam-pumping engine, with two cylinder and one Cornish boiler and heaters. The average duty exacted from this engine during its operation in the year ending April 1st, 1852, was sixty-five millions of pounds raised one foot high by the consumption of one hundred weight of coal. The other stone building encloses a high pressure hoisting engine of thirty horse power, which, in the same year, performed an average duty of seven millions of pounds raised one foot high by the consumption of one hundred weight of coal; also, one powerful Cornish crusher (worked by the same engine) with apparatus for hauling the ore from the dressing floors to it.

The other machinery on the property consists of: a Cornish steam-whim, with Newcastle coil chain of sufficient length to reach to the eighty fathom level on the engine shaft; a large capstan and shears and capstan rope.

The Pit-work is believed to be in good order. It comprises all the necessary plungers, buckets and bucket-rods, main rods, and angle bobs.

In the same prospectus is a report by Joseph Cocking, "formerly Mining Captain at the Works." From his report the following paragraphs are quoted:

The ten fathom level, twenty fathom level, thirty fathom level, forty fathom level and fifty fathom level, are all driven long distances east and west of the engine shaft on the course of the lode through rich bunches of ore, from twenty feet to one hundred feet in length, and between these bunches there is now standing arches of ground that will yield a large amount of vein-stuff, yielding from five percent. to seven percent. of copper. I think there can be from one thousand to fifteen hundred tons of ore obtained from these levels alone, that will yield from five percent. to seven percent. of copper, and can be taken out cheap and at a great profit.

In the forty fathom level east of the engine shaft there was a short bunch of ore not more than twelve or thirteen feet long, and varying in width from ten to eighteen inches, that did not hold up but a few feet above the back of the level, *but going down it gradually increased in width and extended in length, and now at the fifty fathom level this same bunch of ore is sixty feet long, and from sixteen to eighteen feet wide, and will yield from eight per cent. to nine per cent. of copper as stoped from the lode without dressing; there is also in the* forty fathom level west of the shaft a good lode *two hundred feet long,* that will yield a large amount of *eight per cent. or ten per cent. ore.* The fifty fathom level has not been driven so far west as this bunch of ore by twenty-five or thirty fathoms. The sixty and seventy fathom levels have not been driven so far east or west as any of the bunches of ore in the levels above; the sixty fathom level has been driven to within about twenty fathoms of the bunch of ore east of the engine shaft in the bottom of the fifty fathom level, and should this bunch of ore continue good in depth, which I have every reason to believe it will, as it is a very large and regular lode, you have only to drive the sixty, seventy and eighty fathom levels east to this bunch of ore to make it a profitable mine for a long time. Those levels going west will also undoubtedly open good stoping ground. The lode at the eighty fathom level has been cut into about nine feet, and has not yet reached the foot wall; it is thickly spotted with copper, and if the lode was cut through and the levels extended east and west from the engine shaft, it would undoubtedly open good profitable stoping ground.

There is also whole ground from five hundred to six hundred feet long, between the Perkiomen and Ecton Mines, as yet undeveloped, and there is no reason why this piece of new ground should not be as profitable as any ground in the Perkiomen Mine, as there are shafts on each end of it, and there is no other expense required but to drive the levels to open it for stoping.

Ecton mine.—A short distance south of the Perkiomen mine is the old Ecton mine. This mine seems to have been located on a distinct lode. Few detailed descriptions of it are available. The mine dumps would seem to indicate that a fairly large amount of work was done there. On May 1, 1853 at the 54 fathom level the lode was "three feet wide, composed of quartz, spotted with copper pyrites," and at the 66 fathom level it was from 3 to 8 feet wide with "a very promising appearance, but at present poor."

United Mine lode.—Parallel to the Ecton lode but a short distance to the west of it Rogers shows another lode on his map. This is probably what he terms the United Mine Lode although no positive statement to this effect has been found. It seems to have been worked through the Wetherill mine, located about one-half mile south of the Ecton mine. On May 1, 1853 the lode then being worked was said to be "poor and small."

Shannonville South and Port Kennedy lodes.—Almost nothing is known concerning these lodes. Rogers shows the Shannonville South lode on his map as an indefinite vein with a northeast trend located about one-quarter mile southeast of Audubon (Shannonville). The Port Kennedy lode is represented by Rogers as a disconnected vein crossing the Schuylkill River just east of Port Kennedy.

Jug Hollow mine.—Several statements have been found mentioning the Jug Hollow mine, Montgomery County. By some this is supposed to be the same as the Napoleon mine, Chester County, but definite information is lacking.

Morris mine.—The only mine in Chester County that was worked primarily for copper is the Morris mine in the south suburbs of Phoenixville. It too is within the Triassic belt. No definite information concerning this mine has been obtained.

Wheatley mine.—The most important mine of the mineral belt of the Phoenixville district is the Wheatley mine. This has been described many times in the literature, especially the minerals found there by mineralogists. The Wheatley, Brookdale, and Phoenix mines were all located on the Wheatley lode.

Portions of Rogers' description given in his "Geology of Pennsylvania" are quoted.[13]

This remarkably regular silver-lead vein, already one of the most extensive, as respects its developed length, in the country, has been opened and mined at intervals along a range of about 3072 feet. It is first approached from near the water-level, from the S.W. side of Pickering Creek by an adit cross-cut of 410 feet through the red shale; the distance from this point, where the adit turns into the lode to the cross-cut leading from the vein to the main or engine shaft, is 540 feet; thence along the vein to the most western point, now reached in the Wheatley Mine, which is, in the 10-fathom level, 571 feet,—making a total length here wrought, to the date of the first of May, 1853, of 1111 feet. The main adit-level, including the part in the red shale, is 1279 feet long. Between the Wheatley and Brookdale engine-shafts, the distance on the lode is 2076 feet, and at the Brookdale mine the lode has been opened by an adit-level a farther length of 456 feet,—making in all, the developed length already specified of 3072 feet. That the lode is prolonged several feet beyond the present termination of the adit of the Brookdale Mine, is evident to any careful observer; for the surface is marked, in the vicinity of the course of the vein for this space, by lumps of cellular quartz, containing the well-known gossan of the vein and its distinctive ores and minerals. It is certainly an encouraging feature in the vein that it thus so well preserves all its characters over so considerable a length. Although there intervenes a space of about 1501 feet between the southwest workings of the Wheatley Mine and the northeast openings of the Brookdale, within which the lode has not yet been sought for nor proved, there cannot be much doubt that it maintains itself continuously through this interval, and is a regular persistent vein.

In width this vein varies from 1 foot to 2 or 2½ feet, its average size in the Wheatley mine being about 18 inches, and in the Brookdale adit nearly 2 feet. Thus far it gives all the indications of being about as productive in ore in the latter mine, at an equal depth, as it is in the former. While the Brookdale end is somewhat thicker than the other, it is rather more full of quartz; yet the adit there, which is only some 30 feet below the surface, and is at present rather more than 456 feet long, presents, for 400 feet, what miners would call a "kindly lode for ore," with quartz, gossan, phosphate of lead, carbonate of lead, and galena, growing somewhat poorer, however, farther towards the S.W. end. The Brookdale shaft, descending on the lode, is only 75 feet deep as yet but the lode seems gradually to improve as the sinking advances. The dip of the lode in the Wheatley Mine is about 2½ feet to the fathom of 68°; while it is steeper in the Brookdale end, being there about 18 inches per fathom, or 76°. Its mineralogical characters have been sufficiently described already when alluding to it as the type of the more promising lead-bearing lodes of this district. It may be well enough, however, in this place, to call attention to what has been said under the head of "General remarks" upon these veins respecting the prevalence of a soft feldspathic granite on its walls, a sort of rich gossan in its upper levels containing silver, and the gradual reduction in the proportion of the phosphate and carbonate of lead, with a corresponding increase of that of the galena in descending from level to level in the Wheatley Mine. This last fact, showing a progressive replacement of the more easily vaporized ores—condensible only in the upper cooler parts of the vein—by other ores requiring a higher heat to sublime them, gives us as already intimated in a former statement, a right to anticipate a somewhat further augmentation in the quantity of galena as the mine descends. By indicating the energy of the igneous action, which attended the injection of the metalliferous materials in the fissure, these more readily sublimated compounds are in themselves an assurance of the probable permanency and constancy in size of the lode. That this vein is the product of true igneous or volcanic agency from a deep source within the earth, is not only clearly implied by all that has been here stated of its geological and mineralogical features, but is plainly demonstrated by the occurrence of pure volcanic or crystalline sulphur in the cavities of the less compact masses of the galena or sulphuret of lead. Were a conclusive proof of the igneous origin really needed, it would be furnished, I can see, by this interesting fact. Other and equally striking evidences of the force with which the vein was injected will present themselves in the cross courses of trap-rock, intersected and displaced by the lode. We have in the Wheatley and Brookdale Lode, which cuts no less than three of these small dykes of traprock, the interesting proofs that this lead-bearing vein, and, by analogy, the other metalliferous lodes, are of a date even somewhat more modern.

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[13] Rogers, H. D., op. cit. pp. 701-704.

Good ore has been extracted in stopings even between the surface and the adit level (which lies at an average depth of 8 fathoms) ; for example, near the engine-shaft, cross-cut, for a length of about 40 feet. In the next lift, or between the adit-level and the 10-fathom level, the mine has yielded good ore in three several stopings; one, N.E. of the engine-cross-cut, 40 feet long, and 30 feet high; another, just S. W. of the cross-cut, 80 ft. long and nearly up to the adit-level, or about 55 feet high; while the third or largest was both N. E. and S. W. of the W. whim-shaft, and had a length of 214 feet and an average height of some 36 feet.

In addition to this portion already taken out, I would observe that there was in 1853 a mass of ore still above the 10-fathom level at its extreme west end, some 35 feet in length.

Between the 10 fathom and the 20-fathom levels there has been very little ore removed as yet, the chief piece of stoping being a little southwest of the engine-shaft cross-cut. Another mass, about 50 feet long, and only 9 feet high, has been taken chiefly from the S.W. of the whim-shaft; and there is yet a third stoping, on the main lode at the S.W. end of the 20-fathom level, 45 feet in length, but carried up at present no more than about 12 feet on an average.

In the portions of the main lode which seem to promise a profitable future yield, there remains some ore above a long stoping near the W. whim-shaft above the 10 fathom level. The ground S.W. of this old stoping is dead, and beyond it we find 36 feet of good stoping-ground to the present end of the level.

From the 20-fathom level on the N.E. end, N.E. of the engine-shaft, occurs a piece of good ground, almost 40 feet long, near the winze, S.W. of the engine-shaft cross-cut. This first piece is 66 feet long, between the cross-cut and winze. A second piece, beginning 50 feet N.E. of the whim-shaft, and extending for some 250 feet to the present end of this level, though in places quite lean, will pay well for stoping. At the S.W. end of the workings the lode appears of average richness. On the 10-fathom level there is a cross-trap-dike 3 or 4 feet thick, and beyond this the vein is resumed, but is at present thin, being only just at the dike. The 20-fathom level is not as far forward within 150 feet. It ends in a very fair lode, and has very recently increased both in size and richness, the ore part being estimated to be 2 feet thick, and to yield 3 tons of ore per fathom.

Branches from the Main Lode in the Wheatley Mine.

An interesting and encouraging feature in this vein, betraying the energy and extent of the rupturing and injecting force, is the presence of several branch lodes which fork off at an acute angle from the main mass, and, for the most part, reenter it again at a similar obliquity, insulating at the same level at least a thicker or thinner mass of the adjoining rock. These enclosed "horses," as the miners call them, are somewhat entirely insulated in certain mines, sometimes only partially so. In the Wheatley Lode, the principal one points off to nothing upwards, and feathers off in both directions horizontally, by the branch veins, running into the main lode upwards as well as horizontally; but whether it is thus surrounded in the downward direction cannot be known, since it is growing progressively thicker from level to level descending. That this branch lode will eventually enclose the "horse" in the downward direction, seems altogether probable, from its appearing to be so essentially a true branch shot upward and laterally from the main injection of ore.

The branch veins, as now developed, are—

First, A branch vein or offset from the main lode, which turns out and reenters it, insulating a "horse." This branch at the 10-fathom level is 80 feet between its two junctions with the main lode, and at this level it recedes 9 feet at the thickest part of the horse. The horse contains strings of phosphate and carbonate of lead. This branch joins the main lode about 20 feet above, back of the 10-fathom level. It dips steeper than the main lode, underlying not more than 6 inches in a fathom: for at 16 feet below the 10-fathom level, the cross-cut to it is 12 feet long, and it will be 20 feet at the 20-fathom level.

This branch yields good ore throughout, chiefly galena. Its average thickness is about 9 inches, and it is richest where the horse is widest, and thins at its junction with the main lode.

Opposite this branch, the main lode contains galena and phosphate of lead as on the 10 fathom level—good ore, say about 18 inches in thickness.

There is another branch also on the N.W. or underlying side of the lode, visible in the 10-fathom level, but opened and mined from the 20-fathom level. It has been mined 60 feet from the S.W. point of the horse N.E. to where the workings now are; but it has not been worked round into the lode.

This branch, like the other, is nearly perpendicular, underlying not more than 9 inches per fathom. The horse, at the thickest, is about 12 feet, and at the present end of the workings, 5 feet thick, the branch now approaching the main lode.

The horse is streaked with thin veins, and has chunks and strings of galena, carbonate of lead, &c. There are symptoms of other branches or turn-outs of the vein some of them on its S.E. side; but these two, here mentioned, are the only ones now working.

These branches, it will be seen, promise to contribute quite a considerable auxiliary amount of ore to that derived from the main lode, and they deserve to be very carefully sought and pursued.

Of the other or productive half, a careful study of the Wheatley Mine induces me to believe that the average yield in good ore, calculated to the square fathom, is from 1¾ to 1½ tons.

It is in the power of any person, from these data, and from the other elements of length and depth, already presented, to estimate for himself, on the reasonable assumption of a permanency in the averages I have ventured to give, the total future yield of the whole lode, embraced between the limits within which it has been open, and is now being wrought, in the Wheatley and Brookdale Mines.

In support of the general accuracy of my estimate of February 1852, of the quantity and aggregate value of the ore, then accessible in the mine, I beg leave to mention, that I learned from the books of the Company, that the quantity of marketable ore actually extracted from these workings and sold, proved to be almost exactly what I at the time computed it, as it lay unbroken in the mine.

I cannot conclude this description on the Wheatley and Brookdale Lode, and the two mines recently wrought in it, without expressing in distinct terms, my conviction, that the whole vein, as far as opened, holds out a good promise of permanency and richness, or, in other words, of fair remunerative profit, if efficiently and frugally wrought. But to work it to the best efficiency, which in mining is the only true economy, it will be indispensable, I conceive, to drain the lode of the chief part of its water by a powerful pumping-engine and central shaft, stationed at some point between the present Wheatley and Brookdale engine-shafts, competent to relieve both of these mines of their main influx of water, and to make the vein accessible through a greater length and depth than can possibly be commanded by the existing comparatively feeble engines.

Brookdale mine.—Rogers gives the following description of the Brookdale mine.[14]

The Brookdale Lode, or more strictly, the Brookdale end of the Wheatley Lode—for every indication implies that the two mines are situated on one and the same metalliferous vein—has been sufficiently described in referring to the features of the whole under the name of The Wheatley Lode. There would seem to be very little room to doubt that this assumed continuity of the vein really exists; for though both the Wheatley and the Brookdale portions, in certain sections of their length, deviate considerably from the direction of the line joining the most distant shafts, yet the vein appears to return again to this general average course, the departures being neither very wide nor long. The same undulation in its course is noticeable at the Brookdale end which we witness in the Wheatley portion. Though the actual distance on the lode between the S.W. end of the present workings in the Wheatley mine, and the nearest positively proved point in the Brookdale mine, is about 1308 feet, yet the coincidence in direction in the surface vein-stones, and in the ores, and all their accompaniments, is so striking as to convince every attentive observer that the two mines are seated upon one and the same lode. Referring to the general statements given in the preceding sketch of the geological and mineral features of this vein, and its relation to the other veins of the district, I proceed to offer a few notes and observations respecting the Brookdale Mine.

The length of lode opened by the adit-level is about 456 feet but there are decided indications on the surface along the course of it, even a few hundred feet beyond the point at which the adit at present terminates, that the vein still continues. The lode through much of the Brookdale ground or sett, outcrops near the bed of the little transverse valley which descends north from a range of higher land; as a consequence, the adit-level is not deep beneath the surface, being nowhere lower than 6 fathoms, and, on an average, only 4 fathoms.

In this adit-level, the lode is stained with spots of carbonate and phosphate of lead, and with galena, for a length of about 400 feet, or within some 60 feet of the end of the level. The gossans, vein-stones, and ores of the Brookdale Mine are identical with those of the Wheatley, and it exhibits in its hanging wall precisely the same variety of soft white feldspar and quartzose granite which distinguished the same wall of the latter and which I have so very often noticed to be the accompaniment of our richest metalliferous veins.

Above this adit, several tons of marketable ore were procured at no greater depth than some 20 feet; and below this level the vein steadily improves in richness in the shaft.

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[14] Rogers, H. D., op. cit. p. 705.

On the whole, the indications of a productive vein in the lower levels of this mine seem encouraging; but to open the lode satisfactorily, a powerful pumping engine is indispensable. The position of the vein so near the bed of a ravine will render this mine a wet one; and although the present excellent engine of 60 horse power will be competent to the drainage of the first upper levels, it can never grapple with the burden of water to be lifted when the workings grow deep and extensive.

Phoenix mine.—The Phoenix mine was also opened on the Wheatley lode but it seems to have been worked only to a slight extent. In May 1855 the property had a 95-foot shaft and was "developed to an extent of about 400 feet long." This probably means that some drifting was done on the vein.

Chester County mine.—Next to the Wheatley mine in amount of work done is the Chester County mine. As shown on Rogers' map the Chester County lode has a strike such as to cause it to cut the Wheatley lode provided it extends that far. Neither lode has been worked sufficiently to determine whether there is such an intersection.

Part of the Chester County lode extended into the property formerly owned by the Wheatley Mining Co. and was worked by it.

The exact date of opening the mine is not known but when a new company took possession in the first week of June 1850 an adit had been driven from Pickering Creek 837 feet 10 inches in length, four shafts had been sunk, and some drifting done. The adit cut a 5-foot vein, 270 feet from its mouth, which contained, however, only "gossan and spar." 700 feet from the mouth a so-called "copper vein" was encountered "containing spar, gossan, mundic (pyrite), small quantities of yellow copper ore, and occasional stains of green phosphate of lead." The principal lead lode was encountered at 837 feet. A drift had been driven 185 feet on the copper vein that ranged from 22 to 30 inches in width, and on the lead vein 548 feet of drifting had been done. About 20 tons of dressed ore had been obtained prior to June 1850.

Work continued until June 9, 1853 when it no longer became profitable to work the mine on account of the rise in the cost of mining labor and the increasing abundance of zinc ore encountered for which there was no use. During the three years between June 1850 and June 1853 several shafts were sunk and a large amount of drifting done. On the 10-fathom level there were 1342 feet of drifts, on the 20-fathom level 1130 feet, and on the 30-fathom level 916 feet.

From Nov. 1, 1851 to Nov. 1, 1852 the mine yielded 443 tons of ore. A smelter was erected by the company at which the output of this mine as well as that from other mines in the vicinity, from Lancaster County, and from New York and Arkansas were reduced.

The vein is approximately vertical although it varies considerably. Genth in 1851 reported the vein to have an average strike of N.53°E. and an average dip of 75°N. At the point where the writer made observations the strike was N.69°E. with a dip of 75°S. The general character of the vein is indicated by a section given on page 30. It varies from 2 to 5 feet wide. The bulk of the vein consists of decomposed rock, clay gouge, and shattered quartz in which the galena and sphalerite occur as lenses or pockets of varying size.

A trap dike was encountered at one place and near it was some rich copper ore.

The work done in 1918 and 1919 was largely the restoration of the old workings although some drifts were extended and some stopes and winzes driven. A small concentrating mill was erected and some concentrates were shipped to smelters. In one shipment of 100 tons made June 1, 1920, the concentrates averaged 79 per cent lead and 7½ ounces of silver to the ton. There still remains at the mine considerable ore in which the zinc content exceeds the lead.

Montgomery County mine.—The Montgomery County Mining Co. was first organized to work a copper mine in Montgomery County, probably the Ecton or United mine. The venture was a failure. The company later obtained a supplement to its charter permitting it to operate in Chester County and purchased an abandoned mine located a short distance west of the Chester County mine. The former owners had experienced difficulty in smelting their silver-lead ore which was mainly pyromorphite and argentiferous gossan.

In the report of the superintendent, dated May 31, 1853, it is stated that there was one shaft 118 feet deep and three other shallow shafts and an adit. Besides the main vein, four small parallel veins, with widths varying from 3 to 16 inches, were cut by an adit.

Galena, cerussite, and sphalerite were found in considerable abundance. Assays showed the presence of silver in all of them but in larger amounts in the galena, some of which yielded from 15 to 18 ounces per ton.

The mine does not seem to have ever been profitable. The width of the lode and its characteristics are not known.

Charlestown mine.—The Charlestown lode was worked to a lesser degree than the Wheatley, Chester County, and Montgomery lodes and evidently did not prove promising so was abandoned at an early date.

In February 1852 Rogers submitted a short report on the Wheatley and Charlestown lodes in which he gives the following statements concerning the Charlestown lode.

The Charlestown Vein, to which I shall now advert, lies to the westward of the Wheatley Vein, more than half a mile. It is almost strictly parallel with it in direction and is separated from it by two or three lead lodes parallel to both. This vein has been opened by a water-level or adit, south-westward from its north-eastern end for a length of more than 800 feet, and is traceable much farther towards the south-west by its surface vein-stones or gossans, which are stained with phosphate of lead. It is a regular lode, having quite well-defined bounding walls, though inasmuch as the present adit is nowhere at a greater depth beneath the soil than thirty-eight or forty feet, and the whole vein is in a somewhat decomposed state, these walls are not everywhere as well marked as they will be farther down. It occurs in the gneiss, which it cuts somewhat transversely. This gneiss dips towards the south at angles from 45° to 60°, while the vein itself has a dip or underlie of 70° or more towards the southeast. The walls of the lode are chiefly granitic gneiss and granite, the felspar of the granite being half decomposed Its course is nearly straight, being about S. 32°W. with occasional local deflections. In thickness, it would seem materially to exceed the Wheatley Lode, being at least from two to two and a half feet wide, and in some places four feet and even more.

Near the surface, the lode retains very little metallic ore, even in the shallow adit now alone opened in it, we meet only with some of the phosphate and carbonate of lead, with a little galena. Yet, notwithstanding this present poorness in metalliferous matter, so nearly identical are its vein-stones with those of the Wheatley Vein, where there was a nearly equal destitution of metallic ores at the same shallow depth, that I hesitate not to pronounce it, from all its external and general indications, quite as promising a repository of lead. Possibly, the proportion of productive ore in the vein to unproductive mineral matter may exceed that in the other mine, yet it is fully one-half wider between its walls; and this fact, and the increased cheapness of mining thereby caused, will probably quite compensate any comparative difference in richness. Its greater width is very probably one cause of its gossans showing less ore at a corresponding shallow level below the soil: for the decomposition of the mineral materials has from this cause manifestly penetrated to a greater relative depth.

Other lodes.—Rogers' map shows several other lodes and there are occasional references to them by name but no definite information has been obtained concerning them. These are the lodes of the Buckwater mine, a short distance west of the Charlestown mine; the Pennypacker mine south of the Brookdale mine; the Napoleon mine about 1¼ miles west of Valley Forge; and the mine of the Pethericks Penn Mining Smelting Co. a short distance south of the Napoleon mine.

Future Development.

In 1922-1923 two companies were endeavoring to secure funds to reopen the mines south of Phoenixville. Their interests are in the Wheatley and Chester County lodes. They consider that the history of the region and the data available concerning the ore bodies justify the expenditure of considerable sums of money in reopening and reequipping the mines. If they are successful in securing funds, active operations may be resumed at an early date. As in most mining districts there is no positive assurance that the operations will be successful, but there does seem to be considerable justification for a wise and conservative investigation to be made, provided the investors appreciate the true situation, which obviously involves considerable financial risk.

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CLEARFIELD COUNTY.

Eyerman[15] mentions the reported occurrence of argentiferous cerussite on Clearfield Creek, Clearfield County, as doubtful.

COLUMBIA COUNTY.

A lead mine was operated in Columbia County at an early date in the Helderberg limestone in which blende occurs. Cleaveland[16] in 1816 stated that "at Webb's mine, 24 miles from Northumberland, the yellow blende is imbedded in calcareous spar." The probability is that he refers to a mine that was opened in the side of a hill about half way between Lime Ridge and Espy, near the boundary line between Scott and Center townships. White in his report[17] on that district gives the following description.

> Lead and zinc have been found in small quantity near the western line of this township (Center) in the rocks associated with the bed into which, Pohe, Miller, and others have quarried for lime; and some New York capitalists have expended several thousand dollars in attempting to develop the ores in paying quantities. A tunnel for this purpose was driven into the bluff for several rods, just west from where the road turns south to Levi Miller's; but nothing of value was discovered in quantity sufficient to warrant mining, although some rich nuggets of Galena and Zinc ore were found. It is reported that masses of galena more than a foot in diameter, were taken from the rocks. So far as I could determine, these minerals seem to come in the rocks which belong near the junction of the Bossardville limestone and the Upper Salina impure limestones, and are therefore at about the same geological horizon as the Lead and Zinc mine in Northumberland county, three miles below Sunbury.

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[15] Eyerman, John, Mineralogy of Pennsylvania, pt. II, p. 22, Easton, 1911.

[16] Cleaveland, Parker, Elementary treatise on mineralogy and geology, p. 531, Boston, 1816.

[17] White, I. C., Geology of the Susquehanna River Region, Pennsylvania Second Geol. Survey. Report G7, pp. 100, 262, Harrisburg, 1883.

DELAWARE COUNTY.

Gordon[18] lists several places in Delaware County where the rare minerals of uraninite and its alteration product, gummite, bindheimite (?), and also gannite have been found in gneisses and pegmatites.

FAYETTE COUNTY.

The Pocono sandstone of Fayette County has yielded some lead and zinc minerals. In his reports on Fayette County Stevenson[19] describes the occurrence of galena and sphalerite in small quantities as scales or "thin films, like fine veins, interlacing throughout" certain layers of Pocono sandstone in Victor Hollow, a tributary of Georges Creek, Georges Township. The same minerals were noted elsewhere in the Pocono sandstone but nowhere in economic quantities.

HUNTINGDON COUNTY.

The basal beds of the Helderberg limestone of Huntingdon County have yielded some lead ore but not in paying quantities. In his report on the county, White[20] says that:

> Lead ore (galena) in small pieces is often found near the contact of the Lewistown limestone with the underlying Onondaga (Salina) shales. A mile northeast of McConnellstown, shafts were sunk and tunnels driven into the lowest hard limestones in Warrior's ridge. Lumps of galena were found enclosed in the veins of calcite which ramify through the lime rock; but not a ton of lead ore was got from all the diggings. It is quite safe to say that neither lead ore nor zinc ore will ever be profitably mined from the Lewistown limestone formation of this county.

LACKAWANNA COUNTY.

Eyerman[21] says that there is a specimen of sphalerite with siderite from Scranton in the museum of Lafayette College.

LANCASTER COUNTY.

Lead and zinc minerals have been found in several places in Lancaster County and have been mined in two localities. Cleaveland reports the occurrence of galena "in Conestoga Creek, 9 miles from Lancaster, in limestone, and accompanied by the carbonate of lead, calamine, etc." He probably refers to the Pequea mine locality. Gordon reports sphalerite from the dolomitic limestones a quarter of a mile south of East Petersburg and galena in quartz in Salisbury Township.

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[18] Gordon, Samuel G., Mineralogy of Pennsylvania, Phila. 1922.

[19] Stevenson, J. J., Fayette and Westmoreland District: Pennsylvania Second Geol. Survey, Rept. KK, p. 109, KKK pp. 240-241, Harrisburg, 1877-1878.

[20] White, I. C., Geology of Huntingdon County: Pennsylvania Second Geol. Survey, Rept. T3, pp. 129-130, Harrisburg, 1885.

[21] Eyerman, John, Mineralogy of Pennsylvania, pt. I, p. 4, Easton, 1889.

Frazer mentions a specimen of galena obtained near a trap dike in the limestone of Conoy Township. Recently several pieces of galena have been found in the soil of a golf course about 1 1/2 miles south of Lancaster.

No doubt both lead and zinc minerals might be found in many of the calcite veins of the limestones if careful search were made as the same limestone strata in York County have yielded many specimens in a number of places. The only localities deserving of special mention are the Pequea lead-silver mine and the Bamford zinc mine.

Pequea Mine.

Argentiferous galena was mined at the Pequea mine about 1¼ miles north of Marticville, and 1½ miles east of Conestoga for a short time. There is very little information available concerning the mine other than the fact that it was not a profitable venture. A report of the operating company, Lancaster Lead Co. issued in 1863, states that the work started on Nov. 9, 1862. Four veins were prospected and six shafts sunk. The veins were only 3 to 6 inches in width. They were nearly vertical and approximately parallel. One piece of ore weighing 8 pounds is said to have been taken from the workings. The veins were mainly in the limestone but near the contact with mica schist in which some of them were enclosed.

The following description of the ore and its occurrence by Genth is the best one known.

> The galenite of the Pequea Mine in Lancaster County is very interesting. The coarse granular variety containing only a small quantity of silver occurs in a small irregular vein in the mica slate; there is another variety, however, which either alone or associated with quartz, feldspar and mica—a regular granite—forms small lenticular, vein-like segregations in the lower Silurian limestone. It generally shows a very perfect cubical cleavage and is highly argentiferous, yielding as already stated from 250 to 300 ounces of silver per ton.
>
> Besides this variety with cubical cleavage there is another having a distinct octahedral cleavage into which the first sometimes graduates. It was first noticed by the late Dr. John Torrey, who described it in a letter to Prof. G. J. Brush (Am. Journ. of Sc.(2) XXXV, 126), however erroneously stating the locality as being in Lebanon County. The cleavage is, in many of the pieces, eminently octahedral the cubical being less distinct; on heating, however, the latter becomes more predominant.
>
> The specific gravity was found to be 7.63. The amount of silver found by Dr. Torrey was 179 1/5 ounces per ton.

Gordon has compiled the following list of minerals reported from this mine: quartz, adularia (?), chloritoid, phyllite, rutile, siderite, argentiferous galena, cerussite, calamine, anglesite, vauquelinite, and wulfenite.

Bamford Zinc Mine.

The Bamford zinc mine is located about one-third of a mile northeast of Bamford (or Bamfordville), 5 miles northwest of Lancaster. It was visited by the writer in 1921 but other than the determination of the character of the ore and the country rock from the old mine dumps, little information could be obtained as the openings are now filled with water.

History of the mine. The history of the mine has been obtained from a paper by D. B. Landis published by the Lancaster County Historical Society (Vol. VIII, pp. 239-246) and from published mine reports. The discovery of the ore body was made during the Mexican War by a workman digging fence holes. A specimen sent to a chemist showed the ore to contain zinc, lead, and traces of silver. A company was organized under the name of the Lancaster Zinc Co. and up to May 1, 1855, $30,675 had been realized from the sale of stock. A plant for the manufacture of zinc oxide was erected at a cost of $23,776.17. This consisted of ten furnaces with a total capacity of one ton of oxide per day. F. A. Genth, a chemist and geologist of Philadelphia, made a favorable report on the property but for some reason the project failed. The mine report of 1855 states that the sum of $1,989.53 had been realized from the sale of zinc oxide.

The mine remained idle until 1872 when Charles Bamford bought the property and erected an expensive mining and reducing plant. During this period Mr. E. G. Spilsbury, whose report follows, was engaged as superintendent. Bamford is said to have spent about $300,000 with little returns and in 1877 closed the mine, which then had two openings on different veins.

In April 1883 the Lehigh Zinc and Iron Co., owning zinc deposits at Friedensville, Lehigh County, leased the mines and adjoining property for a period of ten years and reopened them. Failing to make the venture profitable, owing both to lack of ore and difficulties with the machinery which had long been idle, operations ceased late in the fall of 1883.

In 1900 an Ohio firm secured leases on the mines and a number of other properties but apparently withdrew without reopening the old workings.

Fortunately good descriptions of the mine by Persifor Frazer and E. G. Spilsbury are given in the geological report on the county.

The following are a few notes concerning the Bamford Zinc enterprise, taken during a visit in July, 1876.

A fuller description by Mr. E. G. Spilsbury follows, giving a resume which includes all his own experience during the entire time that the industry was being carried on.

This mine was worked for white oxide of zinc twenty or thirty years ago.

Mr. Bamford purchased it two or three years ago, and Mr. Tamlin opened it. At an exposure near the works, a limestone appears to dip N. 20°E.-32°. The limestone, rich from impregnation of blende with streaks of more or less argentiferous galena, is about 12 ft. (3.7 meters) thick.

There are two openings, (designated No. 1 and No. 2) on different veins. The former is nearest the smelting works and railroad. No. 2 is about 50 ft. (15.2 meters) further off.

At the surface the dip appeared to be ±N. E., but it changed about 13 ft. (4 meters) below the surface at a small winze shaft, and seemed to take a ±S. W. inclination. At the date of this examination (July 26, 1876) it had not been followed to its junction with the vein in No. 2.

At the above date No. 1 shaft was down about 30 to 40 ft. (9 to 12 meters) vertically.

The depth of No. 2 was about 70 ft. (21.3 meters).

A shaft was sunk in the outcrop of No. 2 vein north-east of both the above, and much calamine (perhaps 50 or 60 tons) was found.

The ore was crushed in a Blake's crusher, and afterwards in a fine crusher, and was dressed in six jigs and three buddles.

Two of the latter were fed from the crusher, and the other one by hand.

The coarse stuff was taken to four jigs from the crusher, and the other two were fed by hand.

The dressed ore was sorted by screens, and roasted and reduced by the Belgian process.

There were about twenty miners in all. All ore but the calamine was crushed in a Blake crusher.

The calamine was placed in a reverberatory furnace and roasted, after which it was crushed fine in a crusher used only for itself and for the clay employed for the manufacture of the retorts, etc.

After being placed in the store house, it was either treated with the blende or by itself according to convenience.

The retorts were 4 ft. 8 inches high, and 8¼ inches in diameter. The condensers (made also of retort clay) were conical, and about fifteen inches high. Coal dust and powdered ore were put into the retorts until full, and the latter were placed on shelves and heated by bituminous coal.

The general average daily yield of spelter was about 1,500 lbs. (710.85 kilograms.)

The average market price was 7.5 cents per lb., but as high as 11 cents has been obtained.

This spelter was put on the market the latter end of September, 1875. They were burnt out in November.

There are four zinc furnaces in one block, with fifty-six retorts and condensers to the furnace. At the date above given but three of them were in operation.

There were two double hearth and two single hearth furnaces. These were occasionally stopped for an hour or two by lack of ore.

The following brief statement of the history of the Bamford Zinc enterprise, near Landisville, is from the pen of Mr. E. G. Spilsbury, the able projector and superintendent of those works, till the suspension of work in 1877.

Sketch of the Bamford Zinc Mine, near Landisville, Lancaster County, Pa.

This mine is situated in East Hempfield Township, on the line of the Pennsylvania Railroad, about five miles West of Lancaster.

The deposit occurs in the form of two parallel bed-veins in the lower Silurian Limestones, near their line of contact with the shales of the same epoch, although so far as developed, the actual line of contact has always been found barren. In this respect the deposit differs from a very similar one in Sinking Valley, Blair County, where the contact lines between the shales and the Limestones are quite productive.

The veins at the Bamford mine are most unmistakably "*bedded* veins, and not fissures or gash veins. They are conformable both to the stratification and dip of the enclosing rocks, their general course being about 74°35′ east of North, and dipping at an angle of 18° from the vertical," (i. e., the dip is N. 15°28′W.-72°). The roofs or hanging walls are, in each case, well defined and regular, although the Limestone of the hanging wall has a decidedly brecciated appearance, is partially decomposed, of a whitish grey color and highly siliceous. It is full of seams and cavities, some of the latter attaining the dimensions of small caves, being 15 to 20 feet long and equally broad, with a height of from 4 to 6 feet. All these seams and openings are completely filled in with a dark red sandy loam, differing in that respect from the Limestone caves of the Lead and Zinc regions of Missouri and Illinois, which are invariably filled with mineral. In none of the cavities examined in this mine have I ever found a trace of mineral.

This broken and dislocated appearance of the upper Limestone bed is not only apparent on the surface, but extends down at least so far as the bottom of the pump shaft, which is 110 feet.

The foot wall, although having a generally regular dip, conformable to the hanging wall, is not so uniformly smooth, but has the appearance of a series of layers, between which the ore bearing limestone of the vein has been intercalated, sometimes to a depth of eight or ten feet.

The limestone forming the foot wall differs very materially from that of the upper beds, being less siliceous, and of a dark blue, and in places almost black tint, and having a very close and compact fracture. I have noticed in places in it small druses lined with calc spar, and frequently filled with Oligiste iron ore, (specular.)

The minerals contained in these veins are the sulphides of zinc and of lead. From the surface down to the permanent water level, a depth of about 18 feet, these minerals have been oxidised by atmospheric influences, and are replaced by calamines and carbonates of lead. The gangue is a limestone, slightly crystalline in spots, but generally very similar to that composing the foot wall. The Galena is chiefly found in bunches, or little strings, running along on or near the hanging wall, whilst the Blende thoroughly impregnates the whole of the vein matter in greater or less proportions. A remarkable feature in the Galenas from this deposit, is the vast difference between the percentages of silver they are found to contain. Specimens taken from one bunch or pocket, will run up to $2,000 of silver per ton, whereas adjoining pieces would perhaps contain only a couple of dollars to the ton. By the eye it is impossible to distinguish any difference between the two minerals, but nevertheless the difference is most probably due to the presence of minute crystals of Tetrahedrite. The average value in silver per ton may be taken as twenty-two dollars.

The Blende occurring here is of a bright golden color, known as rosin blende. It is very pure—the only impurities I have ever found in it being a slight trace of iron and cadmium, and mechanically mixed with it a small percentage of lead. The average of fourteen analyses made at different times on these Blendes, gives:

Zinc	65.87	percent.
Sulphur	32.28	percent.
Iron	.81	percent.
Lead	.34	percent.
Cadmium	.07	percent.
Total	99.37	percent.

The percentage of Blende in the vein varies considerably, but the average of a year's working shows about 17 to 18 per cent.

These veins have been traced on the property for a distance of about half a mile, and ore has been found in an excavation made on the side of Petersburg Township road, just beyond the Pennsylvania railroad. About a mile and a half further north-east, another deposit of calamine was cut through in building the Lancaster Branch of the Reading and Columbia railroad. At that point considerable ore has been taken out, but owing to the desultory manner in which the mining was done, and also from the fact that there is no outcrop here, the soil being fully fifteen feet deep, it is impossible yet to form any correct idea regarding the extent or character of the deposit. It was at first generally supposed to be a continuation of the Bamford veins, but closer examinations prove it to be too far to the northward, and it must either belong to some other belt, or it may be an independent deposit.

At the Bamford mine, both the veins have been opened up and worked down to the 75 foot level, and the south vein has been cut at the 110 foot level.

The north vein has been opened on a length of over 300 feet, had an average width of 12 feet, and has been worked out to a depth of 50 feet, and cut and explored on the 75 foot level. Below the 50 foot level, however, it was found everywhere to be perfectly barren.

The south vein, which was the most regular and the most profitable, has now been worked out to the 75 foot level, and on a length of over 400 feet. The average width is from 14 to 18 feet. Although in some portions the ore was very rich, still the average amount of zinc in the vein never exceeded 12 per cent., and no ore was ever pure enough to treat without a previous concentration, excepting, of course, the surface deposits of calamine. The richest ore occurred at about fifty feet from the surface, and from there down to seventy-five feet. At the 110 foot level, although the vein is well defined, there is little or no ore in it, at any of the points where it has been opened, and what little ore is in it, appears in strings, and not disseminated, as above.

These deposits were discovered as early as 1845, and have been worked off and on with varying successes since then. It was not, however, until 1873, that the present extensive surface and underground workings were inaugurated. The property at that time changed hands for the enormous sum of $100,000 cash, and the purchasers at once set to work to spend another hundred thousand in building smelting works, before making any effort to develop the underground capabilities of the mine. In 1874 it became evident that no sucessful operations could ever be carried on here which were not based on a thorough mechanical preparation of the ores, owing to the fact, as stated above, that the whole vein mass was merely Limestone, impregnated with minute crystals of Blende. The present dressing floors were therefore erected on the Hartz system, and proved a most perfect success and they are today, probably, the most complete and efficient in any of the Eastern States. The capacity of these floors is from forty-five to fifty tons per day.

The calcining and smelting is carried on in furnaces of the Belgian style, adapted to the burning of anthracite coal.

The cost of producing metal from such very low grade ores was necessarily high, though by very great care and economy the average cost for the year 1877 was not over five cents per pound. By the introduction of some more economical pumping machinery this might be lessened perhaps to 4¾ cents, but even at these figures there is no encouragement to resume operations, even if it were proved that the veins become again metalliferous at a lower depth.

The spelter manufactured here was very pure, and acquired considerable reputation for its good qualities. Subjoined is an analysis of it:

Zinc	99.687
Cadmium	.034
Lead	.262
Copper	trace
Iron	.017
	100.000

Gordon gives the following list of minerals reported from these workings: galena, sphalerite, tetrahedrite?, tennantite, calamine, dolomite, smithsonite pseudomorphic after dolomite, cerussite, aurichalcite, and hydrozincite.

The production figures available are those furnished to Siebenthal by E. G. Spilsbury for the years 1873-1876.

Spelter production of Bamford zinc mine.

	short tons
1873	20
1874	86
1875	164
1876	87

Future Development.

So far as known there have been no attempts to reopen the Lancaster County lead and zinc mines within recent years. When they were closed it was the prevailing opinion that it was extremely doubtful whether they could ever be worked with profit. It is true, mining and concentration methods have undergone some change since the closing of these operations, but it is still doubtful whether it would be advisable for any company to expend further time and money in working these deposits.

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LEBANON COUNTY.

In the magnetic iron ore mines of Cornwall a large variety of minerals has been obtained by mineral collectors. Genth[22] states that sphalerite, ranging in color from asparagus green, brownish green and light brown, has been found associated with prehnite in cavities in the magnetite ore.

LEHIGH COUNTY.

Location of Mines.

The most important zinc deposits in Pennsylvania are at Friedensville, in the Saucon Valley, three miles south of Bethlehem. They have yielded large quantities of high grade zinc ore in the past and may be expected again to become an important factor in the zinc production of the country, although the mines are not operating now. Zinc ore has been found in paying quantity only in a very restricted area at and about half a mile northwest from Friedensville.

History of Mining Operations.

Early in the nineteenth century an unusual mineral was found in the soil on the farm of Jacob Ueberroth, half a mile north of Friedensville, but as iron was the only economic mineral known to occur in the region, little attention was given to this strange material. However, about 1830 a wagon-load of the unknown substance was hauled to the Mary Ann iron furnace in Berks County to be tested. Naturally the experiment yielded no metal, as the zinc was all volatilized and escaped.

In 1845 Andrew Wittman, after studying Overman's Metallurgy, experimented with the ore by means of a small crucible in a stove and obtained a few globules of metal but did not recognize it as zinc.

In the same year (1845) Theodore William Roepper, a local mineralogist, who later became the first professor of mineralogy and geology in Lehigh University, while taking an afternoon's stroll in the vicinity of Friedensville, picked up a few pieces of the hitherto unknown mineral and determined it to be calamine. He conducted experiments in Lehman's foundry, South Bethlehem, where he succeeded in making brass from the calamine and native copper. He did not succeed, however, in making spelter.

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[22] Genth, F. A., Proc. Amer. Phil. Soc., vol. 20, pp. 400-401, Philadelphia, 1882.

Roepper induced Robert Earp, a Philadelphia importer, to examine the deposit and obtain a lease on the Ueberroth farm. This being done, Earp mined nine tons of the ore, which was shipped to England in one of Earp's vessels in January, 1846. The temperature of the English furnaces being gauged for roasted ore was not high enough for the calamine, so the report came back that the ore could not be used.

Experiments carried on in this country finally developed a process for the manufacture of zinc oxide from the calamine ore and in the spring of 1853 Samuel Wetherill began the construction of furnaces for the production of the oxide according to a process of his own invention. The furnaces were erected in what is now the south portion of Bethlehem (then known as Augusta). They had a capacity of 2000 tons per annum, were completed October 12, 1853, and on the following day zinc oxide was produced from the Friedensville ore by Wetherill's "furnaces" and "tower" processes combined with Richard Jones' "bag" process of collecting. This process was described by M. S. Henry (History of the Lehigh Valley, pp. 236-7) in 1860, as follows:—

> The entire process of manufacture practised here consists, in effect, of the following operations, viz:—
>
> The ore, pulverized and mixed with coal, is strongly heated in furnaces which are fully supplied with air; the metallic zinc which is thereby extracted in the form of vapor, is instantly oxidized, and the oxide of zinc thus formed, being an exceedingly light powder, is carried immediately from the furnaces by a strong artificial draft, together with large quantities of gases, and such ashes, etc., as are light enough to float in a current of air. These ashes are taken first and separated and deposited with the coarser particles of zinc oxide in rooms provided for the purpose; a part of the pure zinc oxide is afterward caught in chambers, and finally the gases are all strained out by an immense apparatus of flannel and muslin bags, to the inner surface of which the last and finest of the zinc oxide adheres, whence it is removed at proper intervals.
>
> The zinc oxide which is thus collected in the chambers and bags, is in the form of a very white, fine, and flocculent powder, which is compressed by proper apparatus into much smaller bulk, and is then carefully packed into strong, tight, paper-lined casks.

The manufacture of zinc oxide from the Friedensville ore was the second successful attempt of the kind in the United States. In 1852 the New Jersey Zinc Co. in their works at Newark, N. J., had begun the manufacture of zinc oxide on a commercial scale. Their output for 1852 was 1,083 tons, and for 1853, 1,805 tons,—altogether only about 2,500 tons had been produced in the country before the beginning of operations at Friedensville.

On May 2, 1855, by an act of the Legislature, the Pennsylvania and Lehigh Zinc Co., with a capitalization of $1,000,000, and composed of the same men who had already begun operations, was incorporated "for the purpose of mining zinc ore in the counties of Lehigh and Northampton,—of manufacturing zinc paint, metallic zinc and other articles from said ore, and of vending the same."

Attempts to produce spelter were early made, and between 1854 and 1859 Wetherill carried on a series of experiments for that purpose. He succeeded in producing spelter but the process he developed was not economical and the experiments were discontinued. His method was to heat the ore in the open furnace and then draw the vaporized oxide through incandescent anthracite to reduce the oxide. He made a few tons in this way.

In 1857 Matthiessen and Hegeler, two young men fresh from the School of Mines of Freiberg, Saxony, obtained permission to experiment in the plant which the company had erected at Friedensvile. They were successful in making spelter but were not able to make satisfactory terms with the company for the erection of a plant of practicable size.

In 1859 Joseph Wharton contracted with the company for the erection of spelter works of the Belgian type, with retorts made of materials that had been found to be sufficiently refractory, and brought to this country Louis De Gée of Ougrée, Province of Liége, Belgium, to superintend their construction. The Belgian furnaces proved to be successful and in July, 1859, the first spelter was produced.

It is interesting to recall that up to this time spelter had been made commercially at only one place in the country. In 1835-36, at the United States arsenal in Washington, the first brass was produced in this country. It was made from the zincite ore found at Franklin Furnace and Stirling Hill, N. J. and ore from Perkiomen, Pa., and was used in the manufacture of the standard weights and measures ordered by Congress. The method was the one known for hundreds of years of producing brass from native copper and zinc ore. The process, however, was so expensive that it was many years before any other attempts were made to utilize the zinc ores of this country. The first regular manufacture of spelter was started in 1850, using the New Jersey ores. The industry did not meet with much success for several years because the oxide of iron in the franklinite of the ore formed a fusible silicate with the siliceous matter of the clay. Thus the production of spelter from the Friedensville ores was started only a few years later than that from the New Jersey ores and the furnaces erected at South Bethlehem were the first entirely successful zinc furnaces in the United States.

On February 16, 1860, by an act of the Legislature, the name of the company was changed to the Lehigh Zinc Company, by which it is best known. There was much litigation concerning the ownership of the property until 1861, when the company purchased the land outright.

In 1864 and 1865 the company erected a mill for rolling sheet zinc with a capacity of 3,000 casks or 1,680 tons per year. The mill started operations in April, 1865.

From 1853 to 1876 the Lehigh Zinc Co. continued to operate its Friedensville mines without interruption. From the beginning of operations until 1875 this company was the only one operating in the district. It however, never owned the property of the Jacob Correll estate lying just west of the Friedensville church. This property was originally leased by the Passaic Zinc Co., by whom it was sublet to the Lehigh Zinc Co. on high royalties. In 1875 this lease expiring, the Bergen Point Zinc Co. of Bergen Point, N. J., obtained the lease and began operations. For about a year, therefore, until the closing of the Lehigh Zinc Co's operations, there were two companies at work in the region. The latter company continued to operate until 1881.

In 1881 Franklin Osgood, who already owned an interest in the Correll mine, purchased the Lehigh Zinc Co's property, consisting of the Ueberroth and the Old Hartman and New Hartman mines, and organized the Friedensville Zinc Co. New smelters were erected at the Ueberroth and the Old Hartman and New Hartman mines, and ever, from 1881 to 1885 the ores mined were mainly shipped to Bergen Point, N. J., but after March, 1886 were smelted at the works.

Mining operations at the Correll and New Hartman mines continued with few interruptions to November, 1893, since which time the mines have all been idle. The Ueberroth mine was worked for a while in 1883 and again for a short time in 1886. The big pump of this mine was run from September 29, 1890 to September 15, 1891, but merely for the purpose of lowering the water in the New Hartman mine.

At the present time the New Jersey Zinc Co. owns all the mines that have thus far been opened, with the exception of the Correll mine, together with considerable land adjoining.

In 1914 and 1915 extensive diamond drilling was done in the region by the New Jersey Zinc Co., and later the New Hartman shaft was retimbered and new pumps installed. For several months pumping was carried on but the war caused the company to abandon the project for the time being and work has not been resumed since. Diamond drilling was resumed in 1923 and has continued into 1924. The results are not available.

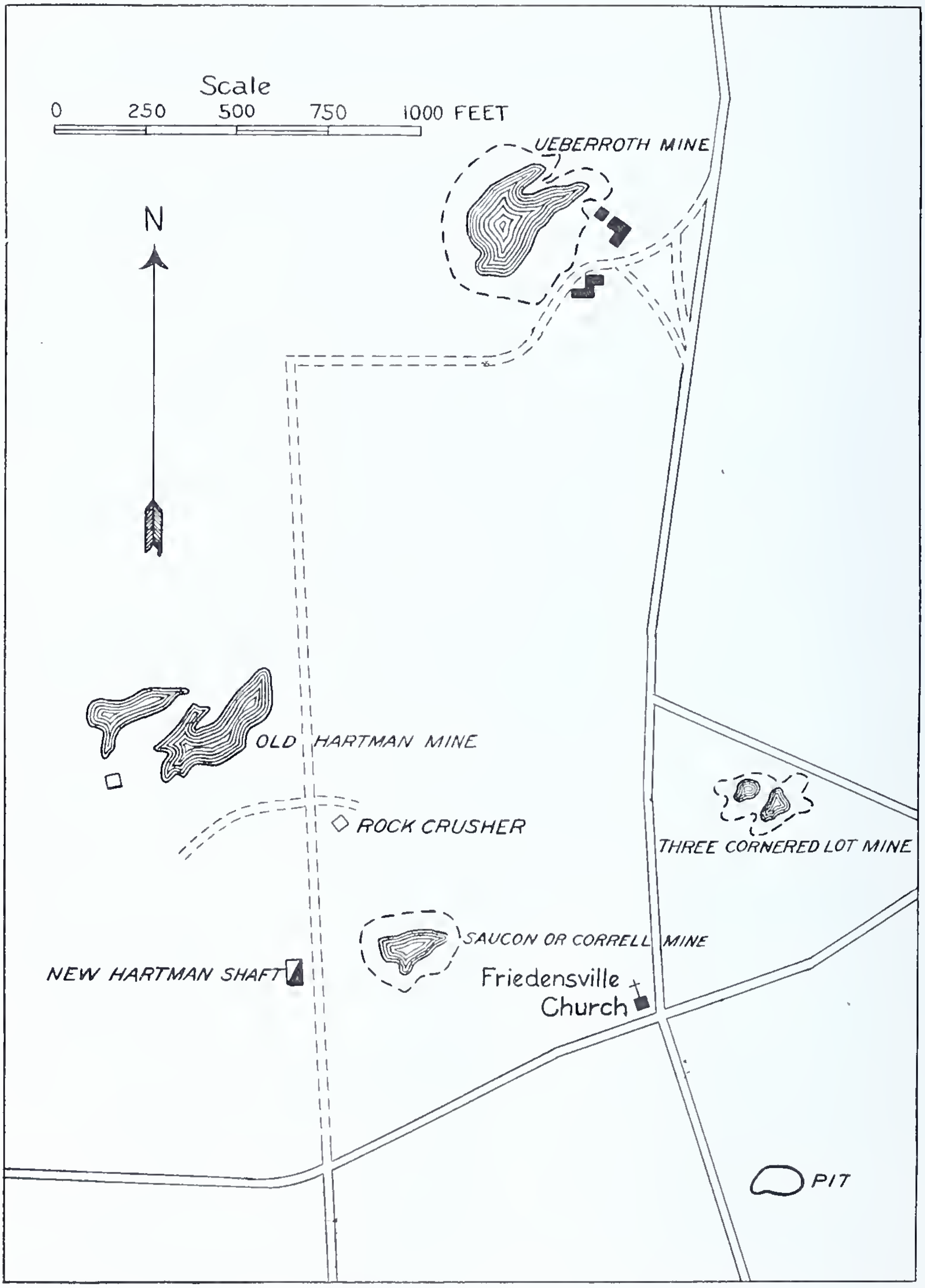


Figure 4. Map of Friedensville zinc mines.

It is estimated that 50,000 tons of spelter and 90,000 tons of zinc oxide, valued at approximately $20,000,000 have been produced from the Friedensville zinc ores. Very incomplete statistics of actual production have been obtained from occasional items in the mining journals.

From October, 1853, to September, 1857, 4,725 tons of zinc oxide were produced. In 1865 the production amounted to approximately 3,000 tons of zinc oxide, 3,600 tons of metallic zinc, and 3,000 casks, or 1,680 tons of sheet zinc, representing about one-half the total production of the country. The president of the Lehigh Zinc Co. stated in 1872 that in certain years 17,000 tons of ore were mined and up to that time about 300,000 tons had been taken from the ground.

In 1875 the Bergen Point Zinc Co. produced 500 tons of spelter and 1,000 tons of zinc oxide from the ores of the Correll mine, and the Lehigh Zinc Co. 1,505 tons of spelter from ores obtained from the Ueberroth and Hartman mines. From 1876 to 1881 the Correll mine is said to have produced about 50 tons of ore daily. The census statistics for 1880 give a production of 20,459 tons of ore.

Distribution of the Ore.

Zinc ore has been found in paying quantities only in an extremely restricted area in the immediate vicinity of Friedensville and about half a mile northwest from that place. Considerable prospecting has been done over a much larger area throughout the Saucon Valley and elsewhere in the Allentown region, but without success. Reports of zinc from other places have been circulated at many times, but have never been confirmed. Traces of zinc have been found in some limestone drill cores about one mile west of Friedensville, in the limonite iron ores about 1½ miles west of that place, and in the Hellertown cave.

Character and Composition of the Ore.

The zinc ores first worked in the Friedensville region consisted almost entirely of calamine, together with some smithsonite mixed with the residual clay formed by the decomposition of the Beekmantown limestone. With increasing depth of mining the calamine and smithsonite decreased rapidly and zincblende (sphalerite) intimately associated with pyrite and marcasite became more common.

The calamine was found in irregular segregations in the clay in fissures in the limestone, or in the porous, partially silicified limestone, often in botryoidal or stalactitic forms. Sheets or plates from 2 to 3 feet square and from one-eighth to a quarter of an inch thick are said to have been frequently found in the crevices in the limestone. These masses of calamine were coated with small crystals of the same mineral. The crystals of calamine are small but clear and lustrous, and range from colorless to yellowish to greenish-blue.

The smithsonite was usually inconspicuous and occurred as white scales or granular masses coating the calamine or blende, or on the walls of the limestone fissures, or as yellowish-brown porous masses. The larger part of the smithsonite mined was amorphous and occurred in botryoidal, stalactitic, or laminated masses. Occasional plates of small clear crystals with vitreous to pearly luster were found. White, gray, or colorless crystals are most common, but greenish-white to greenish-yellow crystals are found. The yellow crystals probably contain greenockite. Druses of smithsonite coating crystals of aragonite and quartz have been found, showing the later deposition of the smithsonite.

The smithsonite and calamine were formed by oxidation of the sphalerite but the depths at which the sulphide was encountered in the different mines were not uniform. In the Ueberroth mine, for example, calamine was found to the depth of 200 feet from the surface; a mass weighing 8,200 pounds from that depth was exhibited at the Centennial Exposition. On the other hand, some sulphide ore was found only a few feet from the surface in the Old Hartman and Correll mines. This difference was undoubtedly due to greater freedom of downward circulation of meteoric water, bearing oxygen, along certain strata, changing the sphalerite to calamine or smithsonite. The vertical limestone strata of the Ueberroth mine readily permitted the surface waters to pass between the bedding planes to greater depths than in the Correll mine and the Old Hartman mine, where the beds of limestone are less highly inclined.

The Friedensville sphalerite or zincblende is of a peculiar character, essentially unlike any other found in the country. In the main it occurs as compact gray to bluish black to black masses having a prominent conchoidal fracture and rarely showing any traces of crystallization. It is translucent in thin pieces and produces a clear ring when struck. Much of it resembles dark blue limestone, from which it is readily distinguished, however, by its greater specific gravity. Sphalerite of a light resinous color and well crystallized is found in small veins in the limestone and less commonly small honey-yellowish crystals are found on the sides of cavities in the limestone. As sent to the works the sulphide ore contained from 35 to 40 per cent of zinc. The noncrystalline structure of much of the ore and the presence of pyrite render its concentration difficult.

Massive pyrite is almost universally found in association with the sphalerite. In many places the sulphide ore consists mainly of pyrite. The large quantity of pyrite has been one of the most objectionable features of the sulphide ore. Within the ore, crystals of pyrite are extremely rare but small cubes can be seen in many places in the limestone. The ease with which some of the massive iron sulphide decomposes suggests the presence of considerable marcasite, although this has not been definitely determined. Melanterite is frequently seen as an efflorescence on the masses of pyrite and marcasite ore.

Greenockite (cadmium sulphide), which occurs in many places in association with sphalerite, is found in the Friedensville mines but only in the amorphous form. It occurs as yellow, greenish-yellow or orange-colored earthy encrustations on sphalerite, calamine, or limestone. Roepper also found it present in clayey material resulting from the decomposition of pyritiferous limestone. A specimen of this material which he analyzed contained 5 per cent of cadmium. The greenockite is said to have been separated from the ore at the South Bethlehem furnaces, but this is doubtful.

Goslarite, the hydrous sulphate of zinc, also known as white vitriol, has been obtained in the Friedensville mines in small quantities. It is formed by the oxidation of sphalerite and occurs as encrustations of the sphalerite and as fine needle-shaped white crystals.

Occasional specimens of hydrozincite were encountered while the mines were in operation. The specimens are white mammillary particles or earthy white masses. Halloysite, resembling cloudy amber with a marked conchoidal fracture, occurs as a rare mineral. The specimens are very brittle and have a very low specific gravity.

The mines furnished considerable quantities of a clay-like material occasionally known as "tallow clays", but in this region described by Prof. Roepper as a new mineral to which he gave the name "sauconite". Genth, in "Mineralogy of Pennsylvania", Report B, pp. 120-121, described it as follows:

> Apparently amorphous, fracture conchoidal: streak brown and shining; translucent on thin edges: translucency increased by wetting. When thrown into water emits a crackling sound. H=1.5: Sp. Gr.=2.66-2.70.
>
> The following varieties have been analyzed by Roepper: (a) pale yellowish-white; (b) ochre-yellow (after having been dried during one hour at 105°C.); (c) Blake (Dana's Mineralogy, 1868, p. 409) analyzed a pale-yellow variety:

	(a)	(b)	(c)
Silicic acid	48.94	46.45	41.36
Alumina	10.66	7.41	8.04
Ferric oxide	3.85	14.28	9.55
Zinc oxide	26.95	22.86	32.24
Magnesia	......	0.97	1.02
Lime	2.42	0.97	......
Potash	......	......	Trace
Water	7.06	6.73	7.76
	99.88	98.69	99.97

> Like all similar minerals, the composition is somewhat variable, owing in part to accidental admixtures, and a replacement of one isomorphous substance by another.
>
> Allowing in the first analysis for a mechanical admixture of 3.45 per cent. of silicic acid (quartz), the oxygen ratio of zinc oxide and lime (RO), to alumina and ferric oxide (R_2O_3), to silicic acid and water are=1:1:4:1, corresponding with the formula: $3(RO.SiO_2)+R_2O_3, 3SiO_2+3H_2O$.

At one time the Lehigh Zinc Co. encountered a considerable quantity of the "sauconite" in fairly pure form and shipped it to the oxide furnaces. Although the material proved to be satisfactory for the manufacture of zinc oxide no further shipments were made as usually it was taken from the mine with the other ore and was washed away in the log washers with the ordinary clay.

Masses of white kaolin are common, although most of the clay contains impurities of various kinds. Quartz is especially abundant and occurs as a metasomatic replacement of portions of the limestone producing a compact quartzite, as thin veins cutting the limestones in all directions, and as small crystals lining cavities in the somewhat porous altered limestones. An interesting variety of fibrous quartz found in the mines has been called "petrified horsehair". Secondary calcite occurs in many places as cavity fillings and as small crystals. The mines yielded many beautiful specimens of aragonite occurring as radiating acicular crystals as much as one inch long in the cavities in the limestone. Most of the aragonite contains some zinc. One specimen analyzed by Professor Roepper yielded yearly 5 per cent zinc carbonate.

Analysis of aragonite.

$CaCO_3$	94.20
$ZnCO_3$	4.73
Insoluble material	0.53
	99.46

As the limestone in which the ore occurs is highly dolomitic, secondary dolomite would be expected to occur. Cavities in the limestone lined with the characteristic crystals of dolomite are common. Ocherous limonite derived from the original pyrite or marcasite is common and occasional masses of turgite are found. One specimen of ocherous limonite in the Roepper collection in Lehigh University shows beautiful laminated mammillary structure.

Pseudomorphs of limonite after pyrite are common in the limestones in close contact with the ore bodies. Impure masses of wad are occasionally seen in association with the limonite.

Asbestos of the variety called mountain leather occurs in places in the crevices in the limestones. Allophane in the form of white botryoidal and stalactitic masses is found in limited quantity. The region has also yielded a small quantity of lanthanite occurring as aggregations of small rectangular crystals of a delicate pink color and a pearly luster. Although the mineral was reported to have been "thrown out from a few feet below the surface by the miners when sinking an exploring shaft near one of the veins of calamine" it is probable that the specimen originally came from the gneiss a short distance to the north. An analysis was made by W. P. Blake.

Analysis of lanthanite.

Water	24.09
Carbonic acid	22.58
Oxide of lanthanum and didymium	54.90
	101.57

Cerium was not detected but was probably present.

The ores of the Friedensville region are remarkably free from objectionable minerals such as those containing lead, arsenic, and antimony, and for that reason the spelter and oxide made from them always commanded the highest prices. The following editorial in the Engineering and Mining Journal of June 12, 1886, is interesting in this connection.

> Lehigh zinc, or spelter, made from the ores of the Friedensville mines, near Bethlehem, Pa., has a world-wide reputation as the purest zinc in the world, and as specially adapted for use in cartridge making; in fact, it is the only zinc yet known that will make a cartridge that will never expand and stick in the gun in firing. The Russian and Turkish governments long ago recognized this fact, and during their last war had expert commissions in this country testing the metal made into cartridges for them, and they even brought over ores from other countries to treat here, in order to determine whether the high quality was due to any special treatment here. It was fully demonstrated that Lehigh zinc is better than any other because the ore is purer, containing neither arsenic nor lead, and that, with Lake copper, it formed the best cartridge metal yet made. Other European nations have recognized the same fact by buying here; but the English government, with its accustomed "deliberateness", could not accept this fact without expensive experience of its own. Fortunately this experience came in a little instead of a great war. In the Sudan campaign, it is said to appear beyond doubt from evidence collected by Lord Charles Beresford, that in one action with the Arabs twenty-five per cent of the rifles were at one time useless by the jamming of the Boxer cartridge, and as this, no doubt, greatly increased the losses of the British, and lacked but little of annihilating the band of heroes who fought their way forward in their vain effort to rescue General Gordon, it has at last attracted the attention of the government, and a contract has been made for a large amount of Bergenport Company's Lehigh spelter, with which new cartridges are now being made. The price paid is said to be the equivalent of $8\frac{3}{4}$ cents a pound.
>
> All the famous mines producing this exceptional ore are now owned by the Bergenport Zinc Company, which has now made contracts to send 2000 tons of this ore to Belgium for treatment.

Occurrence of the Ore.

The zinc ores are found in a region of sharply folded and faulted Ordovician limestones of Beekmantown age. The surface covering of residual clay and glacial debris prevents an accurate determination of the structure. The rocks have been greatly shattered by the earth movements to which they have been subjected and have thus been opened to the active circulation of water.

No extensive faults can be determined from the outcrops and none has been described in the literature, and the inaccessibility of the underground workings at present prevents additional observations. Slickensided surfaces can be seen in many places in the Ueberroth and Old Hartman workings, and zones of limestone breccia that seem to be in part, if not entirely, fault breccia, indicate displacements. At the Old Hartman mine the brecciated limestone is especially well shown in the outcropping ledges. Such evidences of movement as can be obtained indicate that the faulting was confined principally to displacements along the bedding planes.

That the rocks of the region have yielded to the intense strain to which they have been subjected is shown by the numerous narrow quartz veins that penetrate the limestones in every direction. So abundant are these quartz veins that in many places areas free of them that are more than a few inches in diameter are rare. There can be no question that the shattered condition of the limestones in this region has been the most favorable factor in promoting mineralization by permitting active circulation of water.

Less than half a mile north of the Ueberroth mine there is a normal fault that has a throw of more than 2500 feet by which the Cambrian limestone and quartzite formations have been faulted out and the Ordovician limestone has been brought into contact with the pre-Cambrian gneisses. The direction of the fault is approximately N. 80° E. Another fault that has the same general direction but less throw occurs about half a mile south of Friedensville. It is also probable that a parallel fault passes between the Ueberroth and Correll mines, with the Ueberroth and Old Hartman mines on the north side of the fault and the New Hartman, Correll, and Three Corners mines on the south side. This relation would explain why the limestone strata and the main ore veins at the Ueberroth and Old Hartman mines are practically vertical, whereas at the other three mines which are in a line about N. 80° E. the principal ore veins and enclosing limestones dip 35°-45°S.

The Saucon Valley, which is about 7 miles long from east to west and from 2 to 4 miles wide, is a region in which the structure of the rocks is complicated. Close folding and faulting have shattered the rocks to great depths, although in no other place in the valley have the rocks suffered to the same extent as in the Friedensville region. The structure lines have a general direction from northeast to southwest parallel to the general trend of the valley and the gneiss ridges on either side.

The more persistent ore veins are conformable with the bedding planes of the limestone and represent the filling of the openings between the different beds enlarged by solution, or, in places, the substitution of beds of considerable thickness by sphalerite and pyrite subsequently altered near the surface to calamine, smithsonite, and limonite. The accompanying photograph (Plate II, B) of the Ueberroth mine shows the vertical limestone strata and the open fissures where the ore has been removed. In places the veins were as much as 20 feet wide, although in the main only a few feet wide. They varied much in width even though they were continuous for several hundred feet.

The veins following the joints are approximately at right angles to the principal veins, thus breaking the limestone into more or less rectangular blocks. In the Ueberroth mine, where the strata are nearly vertical, this was a serious drawback to mining, because great limestone masses fell when the ore was removed.

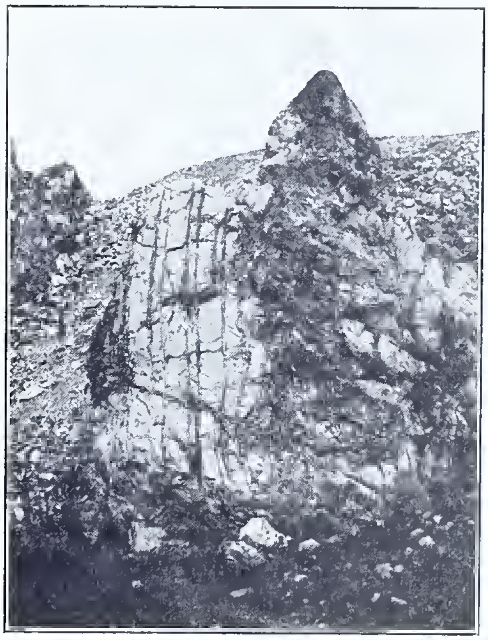
The strike and dip of the main ore veins is fairly regular in each of the mines. The ore bodies pitch along the strike to the southwest at an angle of about 20°. The vein of the Correll mine, which came to the surface in the open cut, was encountered in the New Hartman mine at a depth of 110 feet. The main veins of the Ueberroth mine also seem to pitch westward. Although considerable prospecting has been done east of the Friedensville-Colesville road along the strike of the main Ueberroth veins, no ore has been found.

The veins parallel to the limestone strata with a direction of N. 80° E. were remarkably persistent. The Stadiger vein in the Ueberroth mine was worked along the strike for about 1000 feet. On the other hand, the cross veins following the joints with an average strike of N. 10° W. were comparatively short. Where the two sets of veins intersected the ore bodies were largest and richest. Some of these masses of ore were as much as 60 by 20 feet in cross section.

The vertical extent of the ore bodies has not been determined as ore was found in the greatest depth explored which was about 300 feet at the New Hartman mine.

The oxidized ores, which have been practically exhausted in both the Old and the New Hartman mines, were found near the surface in deep pockets that were formed by solution in the limestones and were associated with residual clay. In the Ueberroth mine they persist to the greatest depth reached, probably in relatively diminished quantity, but of unchanged quality. At lower depths, however, they occur, like some of the blende, as the filling of fissures in the limestone.

PLATE I.



A. Quartz veins along bedding planes in limestone, Friedensville.

C. Dolomitic limestone on south wall of Correll mine, Friedensville.

B. Old Hartman mine, Friedensville, in 1922.

The fissures are openings between bedding planes or joint planes enlarged by solution, but the blende is mostly metasomatic replacements in all mines.

In some of the parallel veins that are only short distances apart, the blende was found almost at the surface, whereas in others the oxidized ores were abundant at a depth of 200 feet. This irregularity was a serious drawback in working the mines because it was inadvisable to mix the two classes of ore.

Origin of the Ore.

The origin of the Friedensville zinc deposits has long been in dispute and there is a justifiable difference of opinion regarding the explanations that have been offered. Drinker supposes "that the zinc was originally disseminated through the dolomite, in the form of carbonate or sulphide." Later the small particles were dissolved by water carrying an excess of carbon dioxide, converted into zinc sulphate by coming into contact with sulphuric acid formed by the decomposition of pyrite, and later were precipitated in their present location as zinc sulphide through the action of animal matter contained in the limestones.

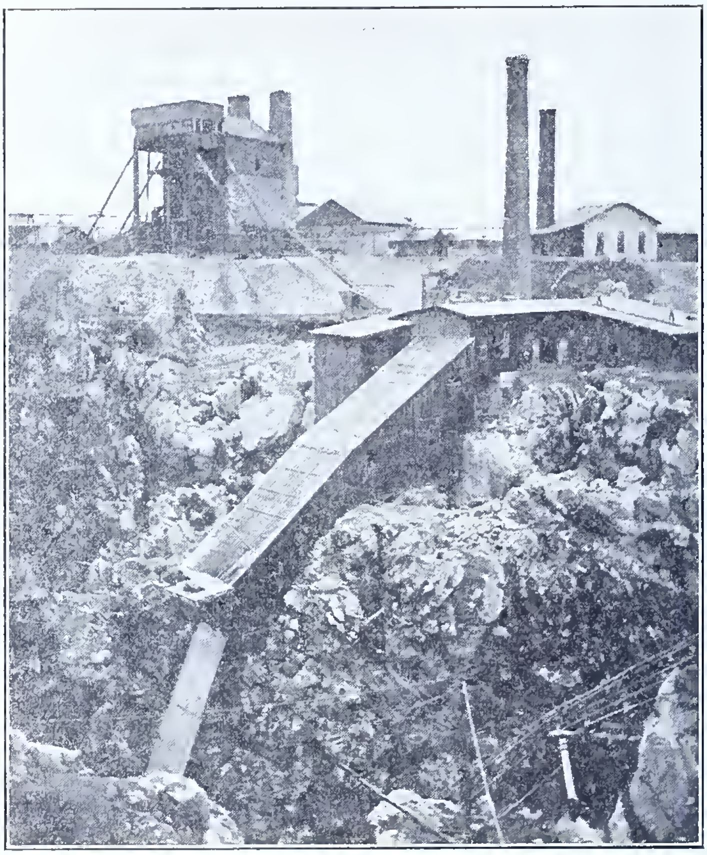
Lesley held somewhat similar ideas and said that "it is probable that they [lead and zinc minerals] were deposited with the limestone in far greater abundance in ancient ages, and were originally brought into the Appalachian sea as soluble salts, together with the lime and magnesia waters of the primeval rivers" and that "the dissolution of the lime rocks has produced concentrated masses of zinc ore." He compared them to the residual limonite deposits which are found in the same rocks but had no explanation for "zinc being substituted in the place of iron."

Clerc suggested a deep-seated origin in his published statement that "they belong to a class of deposits which seem to warrant a belief in their continuance to a considerable depth."

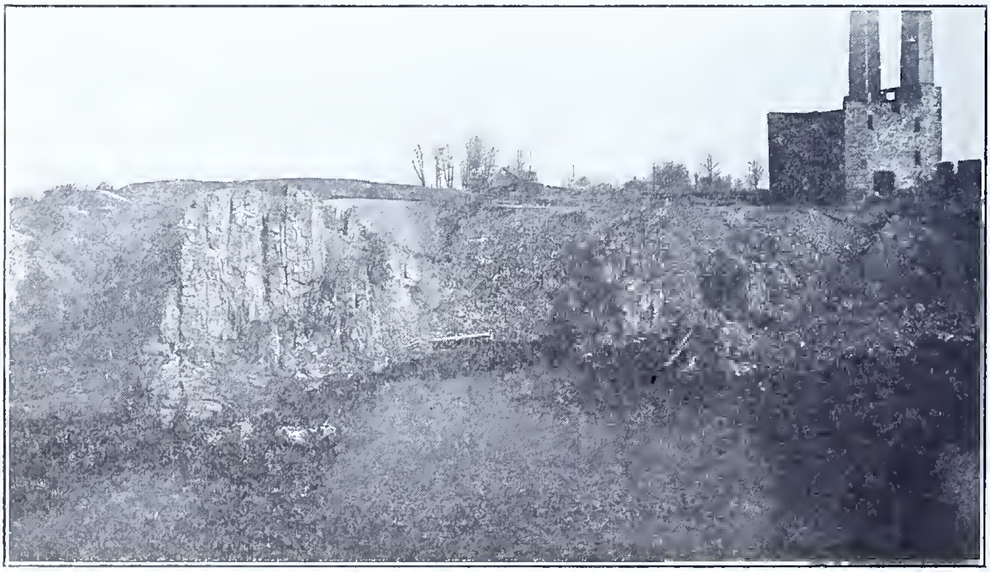
Kemp states that "the veins were evidently filled by circulation from below that brought the zinc ore to its present resting place in the shattered and broken belt."

In forming a theory to account for the formation of the sphalerite, pyrite, and marcasite the connection between the Friedensville zinc deposits and the limonite ore deposits occurring elsewhere in the Saucon Valley should be recognized. Lesley suggested such a connection but did not enter into details. In the iron mines about 1½ miles west of the zinc mines considerable pyrite was encountered in the lower depths and more would undoubtedly have been found had operations continued. The mines, however, were abandoned on the closing of the zinc mines as it was only the pumping of the latter that lowered the water in the mines and made mining practi-

PLATE II.



A. Ueberroth mine, Friedensville, while in operation, about 1877.



B. Recent view of Ueberroth mine.

cable. The iron deposits were not rich enough to justify the pumping necessary to work them. Zinc in small quantity was also present in the limonite.

The primary source of the pyrite and sphalerite must have been the crystalline rocks of the pre-Cambrian, most of which were originally igneous. Pyrite and magnetite are common minerals in the pre-Cambrian gneisses throughout the southeastern part of Pennsylvania. Zinc minerals have not been recognized in these gneisses. There can be little doubt, however, that zinc in some form was present in the ancient rocks that furnished the materials for the thick Paleozoic sediments of this section. In the long ages during which several thousands of feet of Cambrian and Ordovician limestones were deposited the iron and zinc minerals must have been carried into the sea and there precipitated in minute disseminated particles in the limestones as sulphides and carbonates. Many of the limestones show small particles of pyrite and analyses indicate that they contain considerable iron carbonate. The zinc was probably precipitated as a sulphide although part of it may mave existed as a carbonate.

Though much of the iron and zinc may still be disseminated in the limestones, locally these substances have been concentrated by circulating water. The Friedensville district is such a region. It is probable that the limestones of the Saucon Valley originally contained a larger quantity of zinc and iron than other areas of equal extent for more limestones in the Saucon Valley show traces of zinc than elsewhere in the region.

The waters that concentrated the sphalerite, pyrite, and marcasite were doubtless of meteoric origin, for the only post-Ordovician intrusive rocks in the whole region are the Triassic diabase dikes exposed near Coopersburg, about four miles distant. Neither these rocks nor the underlying magma from which they were derived are likely to have furnished magmatic waters which to any large degree segregated the Friedensville sphalerite and pyrite.

If the deposits were formed by meteoric waters it is of practical importance to determine whether the concentration was effected by ascending or descending waters. If descending waters were the agents of transportation the deposits should not extend much below the ground water level; if they were formed through the agency of ascending waters they may be expected to continue to great depths. At the present time ground water level is within 30 feet of the surface in the vicinity of the mines. Since the ore deposits have been found to extend at least to the depth of 300 feet, and with every indication of continuation to greater depths, ascending waters must have brought the sphalerite and pyrite to their present position unless it can be shown that the ground water level formerly lay at

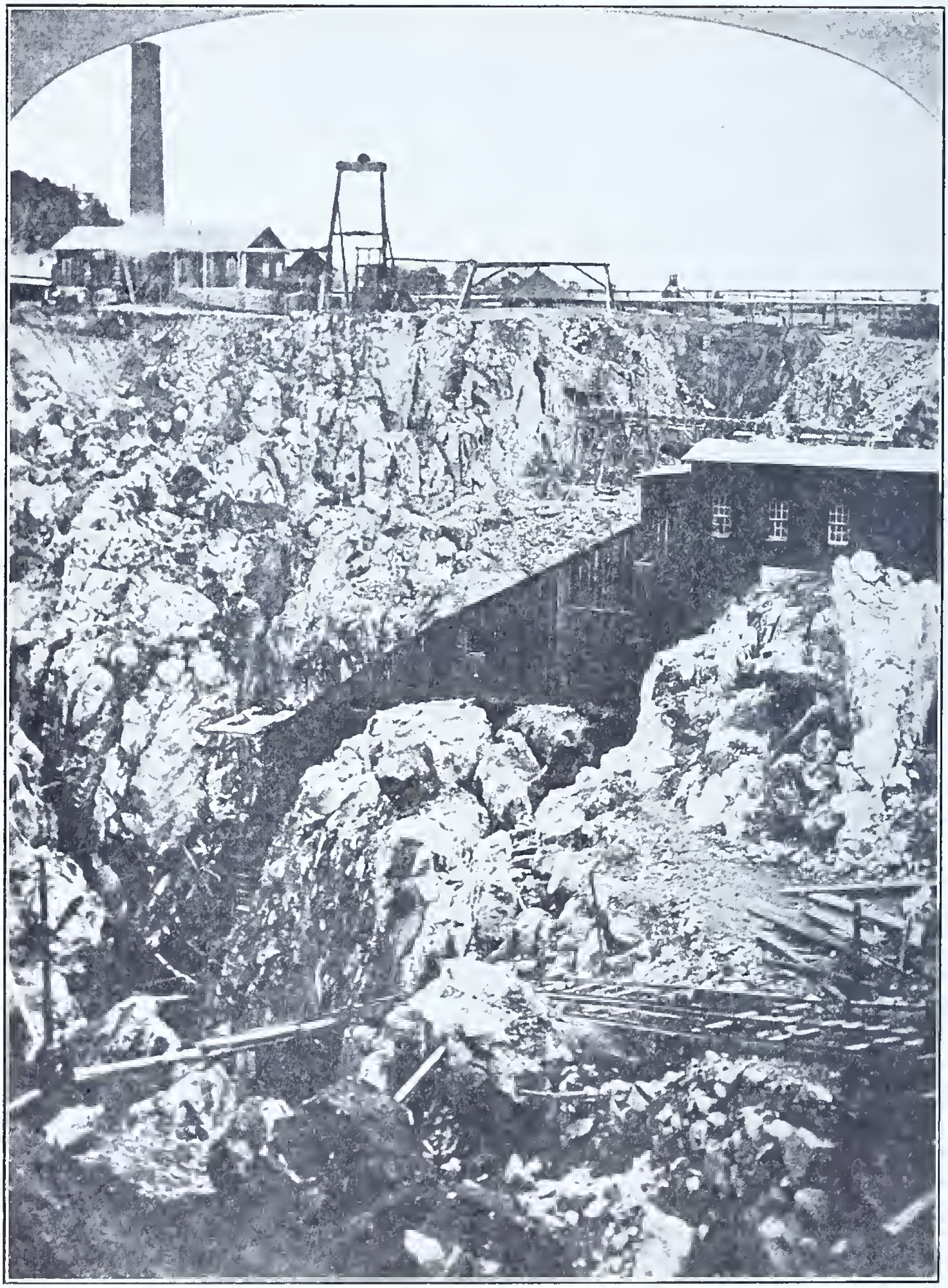


PLATE III. Ueberroth mine, Friedensville, in 1877, showing mill and open pit.

much greater depths than now. However, there is no evidence for this; instead, the indications are that the level of ground water has been continually falling as erosion has deepened the valley.

Throughout the limestone areas of this section water rises in many places under artesian pressure along fault planes and zones of rock shattered by intense folding. Perhaps most of the springs in the district are of this kind. Flowing wells have also been obtained in many places, and indicate the presence of ascending currents of meteoric water. The temperature of none of these is high enough to warrant the use of the term thermal in describing the waters, yet the fact that they are of uniform temperature throughout the year and are slightly warmer than the average surface waters implies a fairly deepseated circulation.

The writer believes that in the formation of the Friedensville zinc deposits downward-percolating waters that contained carbonic acid derived from the atmosphere and organic matter, sulphuric acid, which was derived from the oxidation of pyrite, and possibly some organic acids dissolved the small disseminated particles of zinc and iron carbonates and sulphides and carried them in solution to places where the water found an easy escape upward, as in the shattered and faulted zones near Friedensville. Several hundred and perhaps several thousand feet of limestone and shales overlay the present exposed strata while this work of concentration was most active and consequently the waters were of considerably higher temperature and had greater soluble power than those of the present time. The abundance of marcasite found with the pyrite indicates, however, that the ore-bearing solutions precipitated their load under moderate temperatures.

The pyrite and sphalerite were deposited in part in the fissures through which the solutions passed and in part by metasomatic replacement of the limestone. At the intersections of fissures through which solutions were passing the mingling of waters of somewhat different composition caused increased precipitation and resulted in the formation of the great masses of ore already described. Metasomatic replacement of the dolomitic limestones seems to have been much more common than precipitation of ore in existing fissures. The dense black finely crystalline masses of sphalerite preserve the texture of the original limestone. In some places the contact between the ore and the limestone is sharp and regular but in most places it is otherwise, probably owing to the lack of homogeneity of the greater part of the limestone which permitted the solutions to migrate different distances from the trunk channels.

The Friedensville ore deposits represent the segregation of zinc minerals that were obtained from a great thickness of limestones. The limestones in the vicinity of the mines are probably 2500 to 3000 feet thick, and perhaps as great a thickness has been removed by erosion. The probability is that the ore was collected throughout a thickness of limestones aggregating 5000 to 6000 feet. This is approximately twice the thickness of the limestones of the region but owing to the intense folding to which they were subjected the vertical thickness in the Saucon Valley was probably doubled.

The process of segregation was undoubtedly slow, but it has extended from the end of the Ordovician, when the first great orogenic movements folded and faulted the limestones of the region, up to the present time. The segregation of pyrite by meteoric waters is probably still taking place and no doubt disseminated zinc minerals are likewise being dissolved near the surface, carried downward to great depths, and deposited from ascending waters. Thus the formation of the deposits represents a time interval of millions of years.

The deposits as originally formed consisted almost entirely of pyrite, marcasite, and sphalerite. Calamine, smithsonite, limonite, greenockite and much of the quartz, calcite, and dolomite are all secondary and are the products of alteration by surficial waters. Water charged with silica converted part of the sphalerite into calamine, and carbonic acid changed other portions into smithsonite. In all probability part of the sulphide ore was oxidized to the sulphate and removed in solution, though the richness of the calamine and smithsonite veins seems to indicate that little of the zinc was removed. Part of the pyrite and marcasite was converted into ocherous limonite, but the greater part seems to have been converted into ferrous sulphate and carried away in solution. Some of this sulphate may have been reprecipitated as pyrite or marcasite at lower levels, but evidence of this is lacking.

No indication of the sulphide enrichment of the zinc ore was shown, and it is doubtful whether the sphalerite ore has been appreciably enriched. If it was not the sulphide ore should maintain approximately the same tenor to the lowest depths of profitable mining. In few regions is the sulphide enrichment of zinc ores of much consequence and the Friedensville deposits seem to be no exception. Some secondary sphalerite in the form of small honey-yellow crystals that line the walls of small cavities in the limestones can be frequently found, but it is of no economic importance. Crystals of quartz, calcite, and dolomite occur in a similar manner. As to the paragenesis of the minerals, pseudomorphs of smithsonite after dolomite, and quartz crystals that are coated with smithsonite containing cadmium show the later formation of the zinc carbonate.

Near the surface most of the sulphide ore was changed although some veins that were probably more compact and less permeable were altered to a depth of only a few feet. Great masses of calamine found at the bottom of the Ueberroth mine, about 225 feet deep, show an unusual depth of alteration. There is a strong probability that some of the more permeable veins will yield oxidized ore at considerably greater depths.

As any vein is followed down the blende makes its appearance at the side of the vein whereas the calamine and smithsonite occupy a continually narrowing portion of the center of the vein, thus showing that the downward-percolating waters found an easier passage through the middle of the vein than at either side. The presence of sulphide and oxidized ores at the same level was a serious inconvenience on account of the necessity for mining the two kinds of ore separately, and it is said that much sulphide ore which might have been removed at small cost was left in the mine. For reasons already mentioned and also because the spelter made from the oxidized ores was superior to that made from the sulphide ore the failure to remove all the blende was not considered much of a loss.

Mining.

As the oxidized ore lay at the surface in a mixture of residual clay and limestone boulders it was natural to begin mining by the open-pit method. At the Ueberroth mine, where the ore was first discovered, about 100,000 tons of ore was removed in this way. On the exhaustion of the large surface pocket the ore was followed downward along the crevices in the limestone, which were filled with loose oxidized ore. On account of the falling of large masses of limestone open pit mining was finally abandoned. Shafts were then sunk and the ore hoisted through them. At the Ueberroth and the Old Hartman mines inclined slopes were driven to the deeper-lying ore bodies to the southwest, and from them levels were opened along the veins.

The instability of the inclosing limestone strata required much timbering to hold the rock in place, and many shafts and drifts were destroyed by the settling of great masses of rock. At the Ueberroth mine several shafts had to be abandoned for this reason.

In sinking the shafts and slopes and in driving the drifts it was necessary to remove some of the limestone. Some of this material was hoisted and thrown on the dump, but a considerable portion was put back in the mine to fill old stopes and to underpin loose rock.

Almost at the beginning of mining the water problem became serious. The shattered and cavernous character of the limestones of the Saucon Valley permits easy passage underground so that the water from practically the entire upper part of the valley readily found its way into the mines as they were deepened.

At the depth of 46 feet the flow of water was very strong, and at a depth of 150 feet it became necessary to install what was at that time the largest pumping engine in the world. This engine, called "The President", was started Jan. 29, 1872, and was run continuously until Oct. 28, 1876, and for a few short periods later. This one engine had a calculated pumping capacity of 12,000 gallons a minute from a depth of 300 feet although it rarely if ever raised that quantity. Most of the time it pumped less than 9,000 gallons a minute. It was never necessary to run all the pumps at their full capacity in order to keep the works free of water. Some published figures that give the amount of water pumped are greatly exaggerated.

The quantity of water pumped from the mines suggested a remote source for some of the water, but calculations show that after allowing for 40 per cent evaporation of the average rainfall of the entire drainage basin of Saucon Creek the amount of water pumped from the mines formed only about one-third of the remaining water falling in the valley. Hence there seems to be no reason to doubt that all the mine waters were of local meteoric origin.

When the big engine was running and pumping the water from the Ueberroth mine at a depth of 225 feet, practically all the wells and springs in the Saucon Valley went dry, and lawsuits against the company were threatened. Wells were drained as far to the southwest as Limeport, a distance of 4½ miles, and about 3½ miles to the east. For a time the city of Philadelphia considered a plan to run a pipe line from the mines to Philadelphia as an additional source of water supply.

At one time the water of Saucon Creek, at a point about 1¼ miles southwest of the mine, entirely disappeared through an easy passageway into the mine. By means of refuse thrown into the creek bed the opening was sealed. When the large engine was stopped in 1876 the creek below the mine shrank to a small part of its former volume, and it regained its normal size only after the mine had filled with water. In 1868 the pumping cost was said to be $6 to the ton of ore, and in 1876, when the Ueberroth mine was closed, the pumping cost was said to be $4 to the ton of ore, the greatest item in the entire mining costs. The high cost was due to the fact that only one shift was worked and altogether the daily output was only 55 to 60 tons. For the same cost of pumping a much greater output could have been made.

On account of the different treatment required with the oxidized ores (calamine and smithsonite) and the sulphide ores (sphalerite associated with pyrite) and the difficulty of separating them if they should become mixed, the mining of the different kinds of ores was carried on separately so far as possible. In some places sulphide ore was left in the mines, even though it could have been easily removed. An additional reason for not removing all the sulphide ore encountered was the fact that this ore had to be roasted to remove a large part of the sulphur before it was sent to the furnaces, and the companies were in danger of being enjoined by the courts if the sulphur fumes at Friedensville or South Bethlehem should become obnoxious. It is possible that if the mines are reopened the sulphur gases may be economically utilized in the manufacture of sulphuric acid. The greatest drawback to the profitable production of sulphuric acid will undoubtedly be the large amount of limestone necessarily mined with the ore. The sulphide ore from the Correll mine was made into sulphuric acid at Bergen Point, N. J. For a time the project was profitable, but the increasing amount of limestone in the ore finally caused the company to abandon the attempt to utilize the sulphur.

Milling.

Both the oxidized and the sulphide ores as they came from the mine were mixed with impurities and had to be concentrated before delivery to the furnaces. The impurities with calamine and smithsonite were mainly clay with small pieces of limestone, and a few fragments of pyrite and sphalerite, whereas in the sphalerite ore the chief gangue material was limestone. For these reasons the two kinds of ore required different treatment.

As the oxidized ores were brought from the mine the larger masses were broken by sledges and the richer fragments that happened to be fairly free from impurities were picked out by hand and sent directly to the spelter works. The small fragments mixed with clay were passed through log washers or cone washers. From the washers the ore was discharged on grizzlies or revolving screens and then thrown on picking tables where boys removed pieces of limestone, pyrite, and sphalerite. Most of the concentrate obtained from the washers went to the oxide furnaces.

The water from the washers, which carried the clay and small bits of ore and rock, was drained into settling ponds. Later much of the coarser materials that had been deposited near the inlet of these pits was dug and worked in buddles or tossing tubs and considerable fine calamine and smithsonite were thus recovered. A four-compartment Hartz jig with an eccentric stroke was tried on these sands but was not successful. Sometimes the tailings were found to contain more zinc than the heads. The failure was due to many thin flat pieces of calamine that had a tendency to go with the tailings. The concentrate recovered from the sands was sent to the oxide works. The dried oxidized concentrate as sent to the furnaces contained about 20 per cent zinc.

The intimate mixture of the sphalerite ore and the limestone rendered concentration difficult. In blocks of ore that showed complete gradation from pure sphalerite into pure limestone a clean product could only be obtained after extremely fine grinding. The result was that during the period of most active operations the richer ore was picked by hand and sent to the roasting furnaces or roasting heaps and the remainder thrown aside.

After 1876 sizing and jigging of the sulphide ores was tried. Hand jigs were first used, and these later replaced by Hartz jigs having several compartments. They were not entirely satisfactory, as the tailings were always high in zinc.

The best of the sulphide ore was roasted in reverberatory furnaces for spelter. Often the lower grade ore was heap-roasted and sent to the oxide furnaces or re-roasted in the reverbatory furnaces and sent to the spelter works.

The best of the hand-picked sphalerite ore contained from 42 to 44 per cent zinc; the remainder contained from 15 to 25 per cent zinc.

Outlook for future development.

A common belief that the Friedensville mines were closed on account of the exhaustion of the ore is incorrect, because the ore bodies were as large in the lowest workings as near the surface, the veins gave no evidence of dying out as the depth increased, and the sulphide ores showed little change in tenor. How much ore remains is purely a matter of conjecture, but there is every reason to believe that the mines can still furish a large tonnage of sulphide ore as well as considerable calamine and smithsonite ore.

Another reason frequently heard for closing the mines was the threatened litigation by the farmers whose wells were drained by the pumping that was required to keep the mines free of water. This explanation is likewise without foundation, as the courts have repeatedly upheld the principle that no mining company is liable for damages incurred by the withdrawal of water from previous users so long as this is necessary in order to remove the ore and the water is neither sold nor disposed of in such a manner as to damage other property.

The chief reason why the Lehigh Zinc Co. closed its mines, which consisted of the Ueberroth, Old Hartman, New Hartman, and Three Cornered Lot mines, in 1876, was its inability to compete with the New Jersey Zinc Co. in the manufacture of zinc oxide made from the zinc ores of Stirling Hill and Franklin Furnace, N. J. or with the companies operating in the Central States in the production of spelter.

The Lehigh Zinc Co. owned the Wetherill patents for the manufacture of zinc oxide, and had previously prevented the New Jersey Zinc Co. from producing zinc oxide from the New Jersey ores by bringing suit for infringement of patent. The Wetherill patents having expired in 1876, the New Jersey Zinc Co. was about to enter the field with new oxide furnaces. As it was costing the Lehigh Zinc Co. from $4 to $6 for each ton of ore raised merely to pump the water from the mines, while the ore at Sterling Hill, according to the Engineering and Mining Journal of Sept. 30, 1876, could be loaded on the cars at a cost not exceeding 75 cents per ton, it was foreseen that competition would be ruinous to the Lehigh Zinc Co. An agreement was therefore made by which the Lehigh Zinc Co. closed its mines and contracted with the New Jersey Zinc Co. for 1,000 tons of ore a month from the New Jersey mines for a period of five years.

Clerc, who was familiar with the operations of the Friedensville mines at that time says:—

> The causes which led to extinction of the Lehigh Zinc Company and the abandonment of the two first named (Ueberroth and Old Hartman) mines were briefly these: the impossibility of competing successfully in the oxide market with the owners of the big mine in Sussex County, New Jersey, after the expiration of the patents covering the oxide process left them free to take the trade, or in the sheet zinc and metal market with the western smelters using cheaper and richer ores, at a time when a general depression of all manufacturing enterprises made it unusually burdensome to carry the heavy bonded indebtedness incurred during a period of high prices and general inflation in acquiring mines and putting up machinery to work them. Under more favorable circumstances it is probable that these mines could have been profitably worked for years to come: for although the pumping expenses were heavy, they were not excessive, considered as a royalty on the ore, and these charges per ton would diminish in proportion to the amount of ore mined.

Description of Mines.

Ueberroth mine.—The Ueberroth mine was the largest and most profitable of all the Friedensville mines. It was worked continuously from 1853 to 1876 and for short periods in 1886 and 1891 and produced about 360,000 tons of calamine and smithsonite ore. In no other mine in the region did the oxidized ore continue to such depths. To a depth of 150 feet the oxidized ores were found between loose blocks of limestone, some of enormous size. At that depth, however, the limestone became solid and the ore veins, which were 12 to 40 feet in width, had well-defined walls. The limestone strata and the main ore beds which lie between them are practically vertical in the Ueberroth mine and strike about N. 80° E.

Two very important veins in this mine, known as the Stadiger and Trotter, were worked continuously for a distance along the strike of about 1000 feet. Another productive ore body was known as the Blende vein. This vein was not worked so extensively on account of

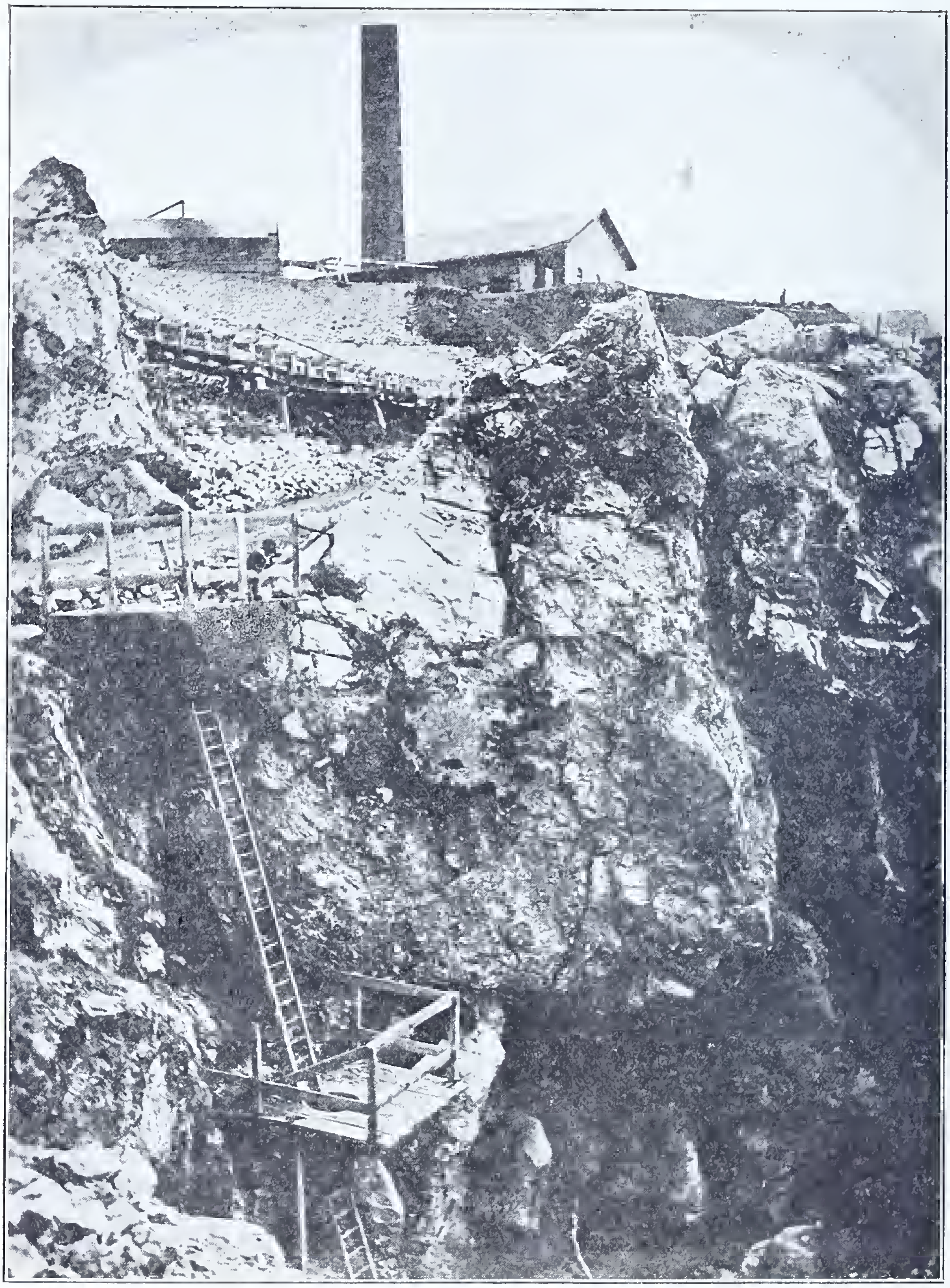


PLATE IV. Ueberroth mine, Friedensville, in 1877, showing character of upper workings.

the larger amount of sulphide ore which it contained. At the deepest level worked this vein was well-developed and yielded ore running about 30 per cent zinc. One-third of the ore was rich enough to be sent directly to the smelters; the remaining two-thirds, however, required concentration.

Clerc gives the following description of this mine:

> The ore came close to the surface, and a very rich pocket was found in the clay above and around limestone bowlders, which is estimated to have produced 100,000 tons of ore. When this body of ore was exhausted, the ore was followed down in crevices between the bowlders. These crevices lie in planes parallel to the bedding of the limestone, or in planes perpendicular to it, and preserve great regularity in their position, and a parallel course for several hundred yards in a northeast and southwest direction; they are nearly vertical, and at the depth of 225 feet, to which the mine was worked, showed no signs of closing up. The ores at first were exclusively calamine and smithsonite, but at greater depth blende made its appearance, coating the walls of the crevices, and in some cases penetrating into them several feet; in other cases segregated as rich seams, which nearly filled the cross openings. At first it was confined to the northeastern end of the mine, but at the lowest depth reached it could be traced almost continuously to the extreme southwestern end. The dip of the ore body appeared to be regular, and to the southwest. Six of these parallel crevices were worked, and about as many crossings; and where they intersected rich bunches of ore were found, some of which were as much as 60 feet across and 20 feet thick. All the indications seemed to point with increasing certainty to the existence of a backbone or underlying deposit of blende, out of the reach of the action of meteoric waters, from the continuation of which the oxidized ores have been derived. Timbering the mine was always a serious difficulty, but the greatest obstacle to be overcome was the water. Even at a depth of 46 feet the flow was already very strong; at the depth of 150 feet it was found necessary to put in what was then the largest pumping engine in the world. This engine, which is a single cylinder, double acting, condensing, walking beam engine, with a pair of flywheels, has a 110-inch cylinder and a 10-foot stroke, and is calculated to work four 30-inch plunger pumps and four 30-inch lift pumps, with 10-foot stroke, and to take water from a depth of 300 feet. At the time it was stopped it was running from six to seven strokes a minute, and was working three pairs of 30-inch pumps and one pair of 22-inch pumps, and was easily handling all the water that came to them. The pump shaft and foundation for the engine were no less remarkable in their way. The latter was built up from the solid rock, 60 feet below the surface of the ground, of hewn blocks of Potsdam sandstone; the former, which measured 30 feet by 20 feet in the clear, was started on a small crevice, and timbered with 12-inch square yellow pine sticks, and divided into three compartments, and further strengthened by two open brattices of the same heavy timber. When the pitch of the vein carried it out of the shaft the rest of the depth was sunk through solid rock.

Several shafts were sunk at this mine but these have been destroyed by caving. At present the old open pit which is approximately circular and measures about 480 feet in diameter is filled with water to within about 30 feet from the surface. Nearly all the buildings which were formerly near the mine have been completely razed; the pumping engine house and office, the only ones remaining, are in ruins. (See Figure 5.)

NOTE. Figures 5, 6, and 7 were copied from a map of the property of the Friedensville Zinc Co. made by Jacobs & Davies, New York, May, 1899, and furnished to the writer by the New Jersey Zinc Co.

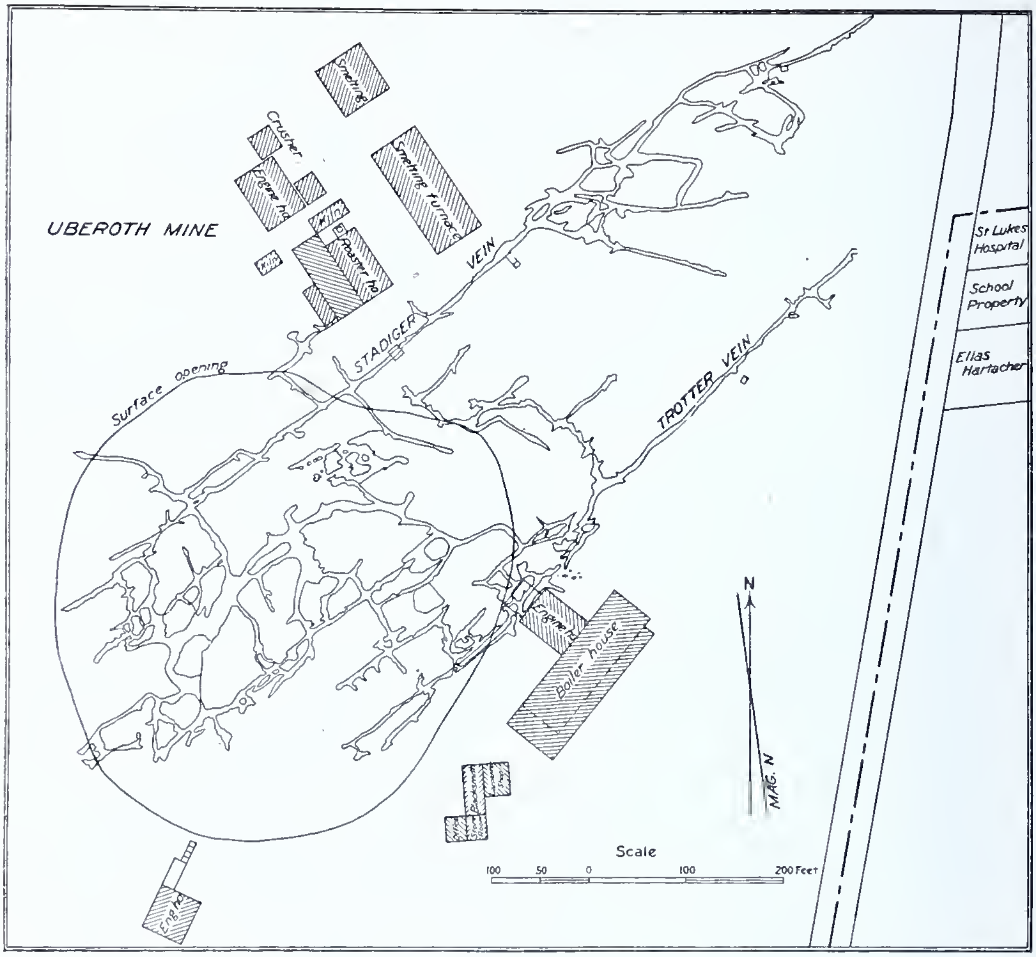


Figure 5. Map of Ueberroth mine.

Old Hartman mine.—About a quarter of a mile southwest of the Ueberroth mine is the Old Hartman mine now consisting of two open pits about 400 by 250 feet in extent, both nearly filled with water. As in the case of the Ueberroth, the Old Hartman mine was first worked exclusively for calamine and smithsonite but large bodies of blende were encountered nearer the surface than in the Ueberroth mine. The oxidized ores were worked to the depth of 150 feet although much sulphide ore was found nearer the surface. The last work done in this mine was the driving of a slope to work a fine vein of sphalerite ore.

The limestones of the Old Hartman mine show much brecciation but are less cavernous than the Ueberroth mine. The water problem here was less serious and the mine was operated for a year after the large engine at the Ueberroth pit was stopped. Had grouting been employed the necessary pumping might have been considerably reduced. At the present time the water level in the two openings is somewhat lower than in the Ueberroth pit, which seems to show an independent source.

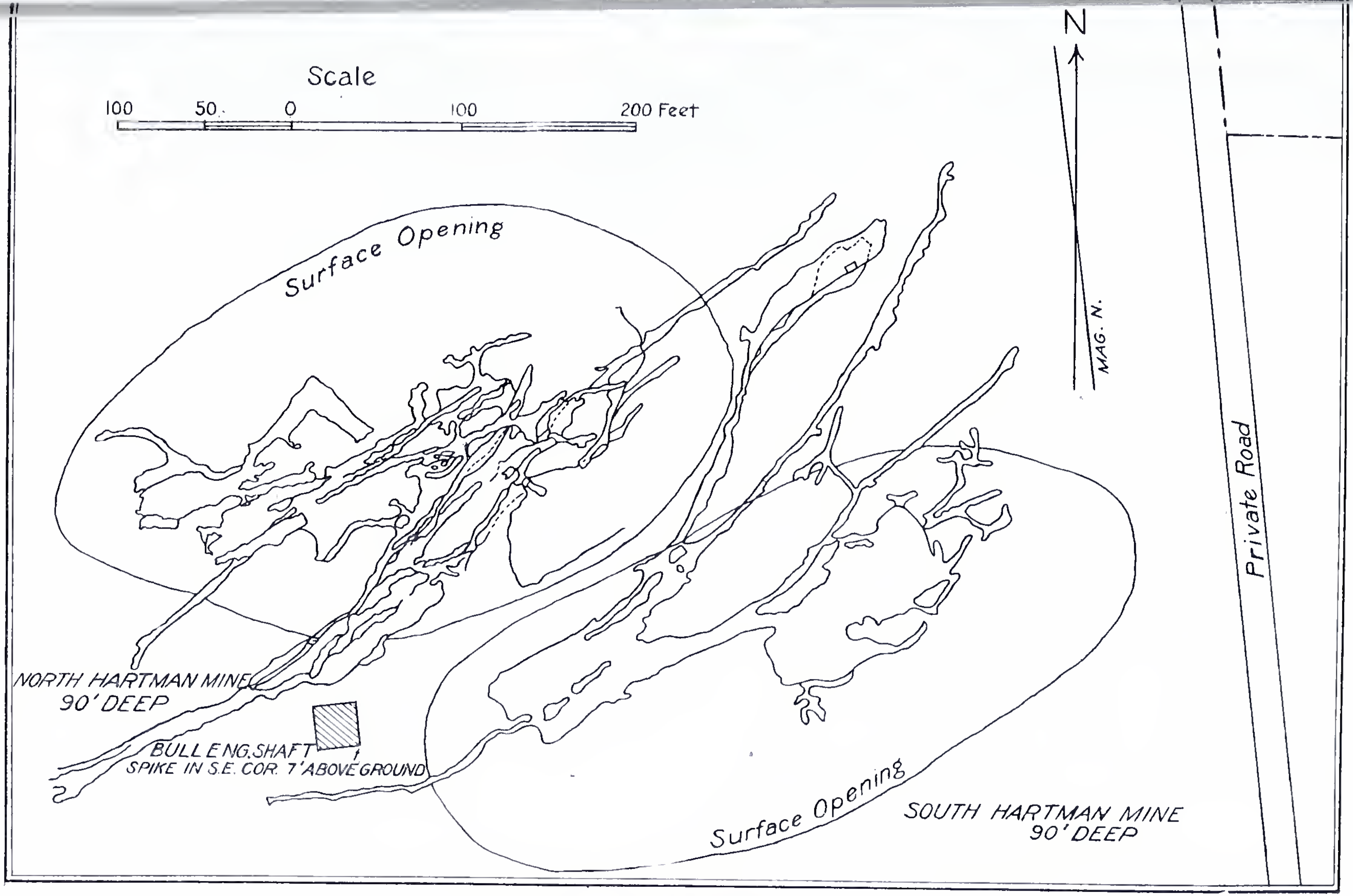


Figure 6. Map of Old Hartman mine.

The Old Hartman mine was worked both by open cut and by shafts sunk in the limestones. The vein system is similar to that of the Ueberroth mine although no veins were followed so far. The veins of the two mines seem to be entirely distinct.

Correll mine.—The Correll or Saucon mine is about one-eighth mile southeast of the Old Hartman mine. It was actively worked as early as 1859 and much of the time between that date and 1881, but since that time it has furnished little ore. The mine produced less oxidized ore in proportion to the sulphide ore than did the Ueberroth mine. The mine was worked by open cut until 1876, after which underground mining predominated, and extended to a depth of 200 feet. The limestone strata and the principal ore veins which lie between them dip S. 30°—40°. The limestones are regular and show few effects of disturbance or of solution.

In 1876 a 12-foot vein of sulphide ore was being worked. At greater depth this width increased to 40 feet and in one place to 50 feet. The whole length of working in the Correll mine was about 700 feet along the strike. The veins were worked to the western limits of the property of the Correll estate and are continued in the New Hartman mine.

The open pit of the Correll mine, now partly filled with water, measures approximately 200 by 300 feet.

New Hartman mine.—The New Hartman mine, which adjoins the Correll property on the west, is the only mine in the region that was worked exclusively by underground methods. The ore was struck in a vertical shaft at a depth of 110 feet and continued downward

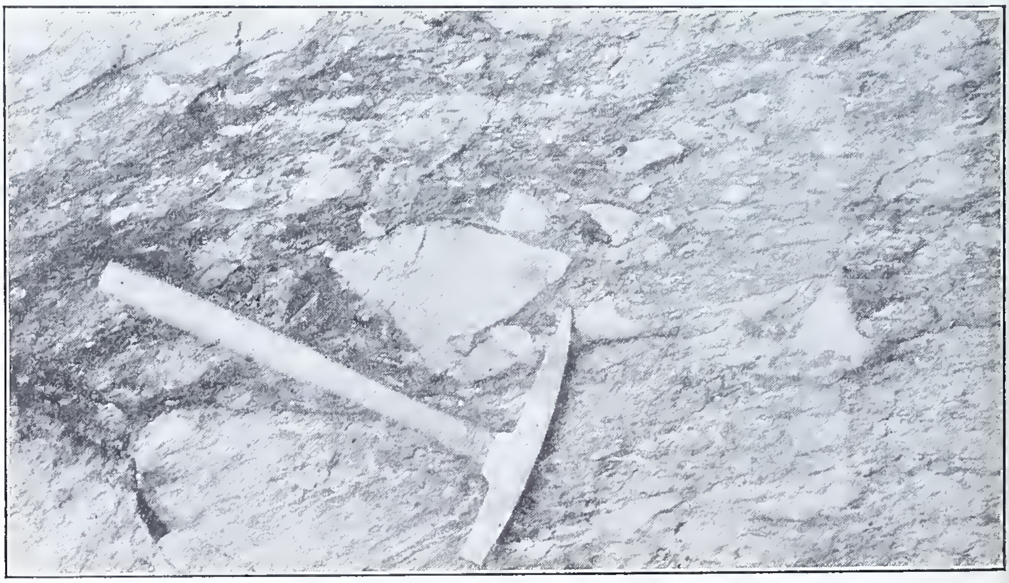


PLATE V. Limestone breccia in Old Hartman mine, Friedensville.

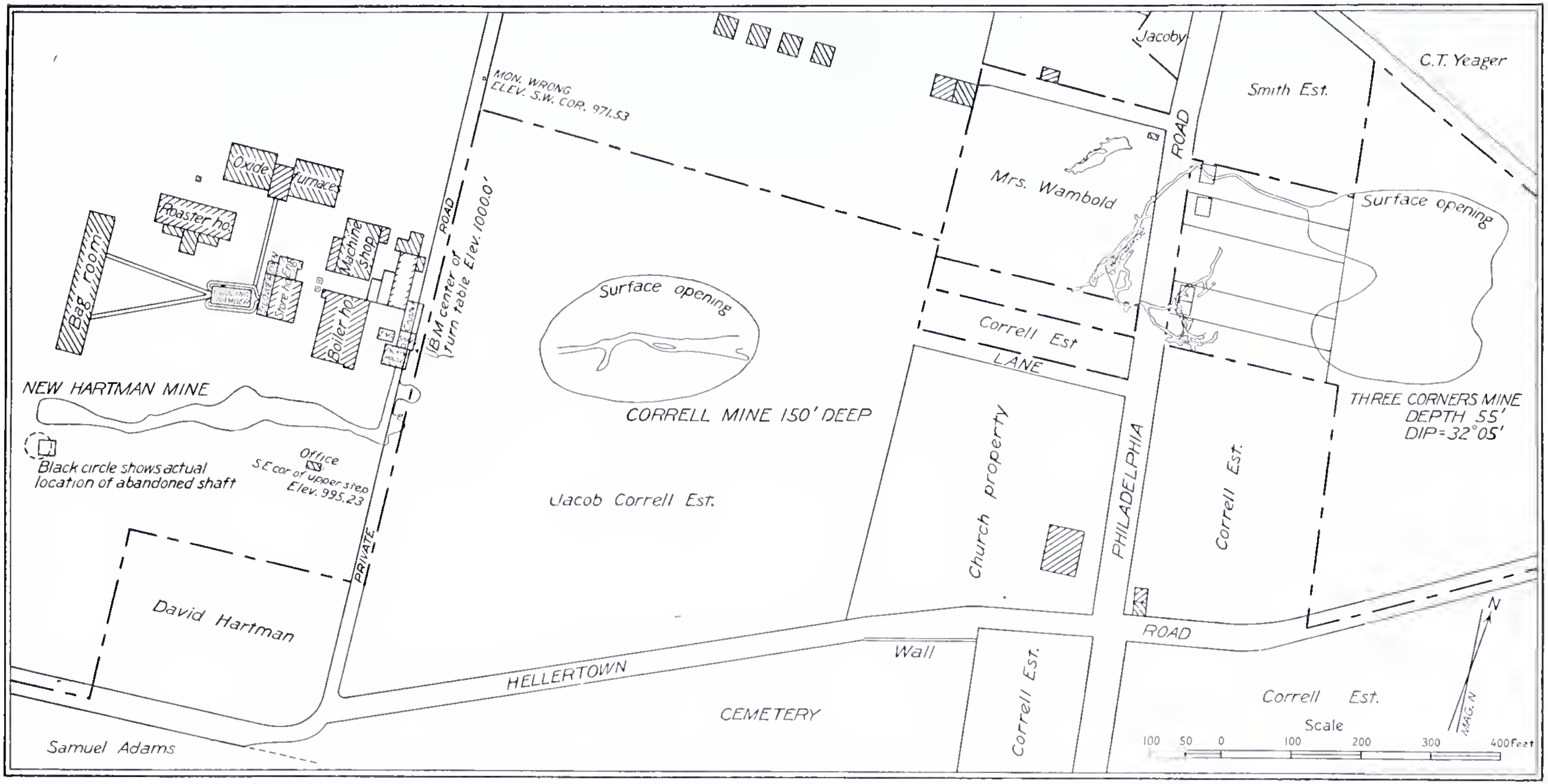


Figure 7. Map of New Hartman, Correll, and Three-cornered Lot mines.

to a depth of 200 feet. Very little oxidized ore was found. When work ceased the principal ore vein was said to be 50 feet wide. Its strike was almost due east, and the dip was 35° S.

Three-Cornered Lot mine.—This mine is east of the Friedensville-Colesville road about 700 feet northeast of the Friedensville church. The open cut which is partly filled with water, is irregular in shape with an average diameter of about 250 feet. Here, as in most of the mines, open-cut mining finally gave place to underground mining, and several veins were followed under the road and beneath the property that lies west of the road north of the church. The veins undoubtedly belong to the same system as those of the Correll and New Hartman mines and have the same general strike and dip. The limestone strata exposed dip 35° S. and strike N. 85° E.

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LYCOMING COUNTY.

The presence of sphalerite and galena in the upper portion of the Catskill formation along Roaring Branch in Lycoming County is recorded by Meyer.[23]

MONROE AND PIKE COUNTIES.

Because lead and zinc ores in considerable quantity have been found in the nearby region of New York State active search for similar deposits has been made in Monroe County but with little success. White says in his report[24] on the region that traces of lead, zinc and copper have been found in Hamilton strata in Westfall Township, Pike County, near Port Jervis, and a little copper ore and zinc blende on the farm of I. Turn in Middle Smithfield Township, Monroe County.

MONTGOMERY COUNTY.

The lead and zinc mines of Montgomery County are near the western part of the county, a short distance from Audubon (formerly Shannonville). They constitute a part of the mineralized region usually called the Phoenixville Mines District. It seems best to describe the district as a unit and as it lies mainly in Chester County it is discussed under that division of this report.

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[23] Meyer, Abraham, Proc. Acad. Nat. Sci. Phila., vol. 45, pp. 194-196, Philadelphia, 1893.

[24] White, I. C., Geology of Pike and Monroe Counties: Pennsylvania Second Geol. Survey, Rept. G6, pp. 196, 217, Harrisburg, 1882.

NORTHAMPTON COUNTY.

The writer has found small quantities of galena and sphalerite associated with calcite forming small veins in the pre-Cambrian serpentine quarries along the Delaware River just north of Easton.

Eyerman[25] says that in 1888 he obtained some good crystals of calamine of a dark color on limonite and coating the interior of geodes from an abandoned limonite iron mine shaft on the land of S. von Steuben, ¼ mile west of Dryland Station.

NORTHUMBERLAND COUNTY.

In Northumberland County the Helderberg limestones have yielded more lead and zinc ores than the same limestones have produced in any of the other counties of the State, but even here the ores were not found in sufficient quantity to make a profitable mine. The best description of these ores is that given by White[26] in his report of this region.

> Lead and zinc have been found in considerable quantity just above the base of the Bossardville limestone, along the river between Sunbury and Selinsgrove Junction, in Northumberland County.
>
> The mine is reported to have first been discovered about 40 years ago, and some of the ores shipped east in barrels on the Pennsylvania Canal; but as the results were kept secret, no one pursued the matter any further until the last year, (1882) when Mr. Doughty of Shamokin undertook a systematic development of the ore. The mine now being developed comes at the very crest of the Selinsgrove arch, near the 135th mile-post on the N. C. R. R., and the ore occurs about 10 ft. above the base of the Bossardville limestone. It occurs in "strings" and "pots", mixed with a large amount of muddy rubbish and resembling the deposits from a stream of turbid water flowing among rocks.
>
> The course of the deposit appears to run with the strike of the beds, which is here nearly east and west; though the ore has not been followed into the hill far enough to determine much about its extent or manner of deposition.
>
> Several tons of ore lay on the dump when I visited the mine, and from pieces selected at random Mr. McCreath made the following analysis:

Metallic lead	24.191
Metallic zinc	31.954
Metallic copper	1.389

> Both the lead and zinc occur chiefly as sulphides, while the copper is in the form of carbonate.
>
> From this analysis it is plain that Mr. Doughty will have a valuable mine if he can find the ore in sufficient quantity.

Lesley[27] in his final summary report gives practically the same description.

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[25] Eyerman, John, Mineralogy of Pennsylvania, pt. I, p. 29, Easton, 1889.

[26] White, I. C., Geology of Susquehanna River Region: Pennsylvania Second Geol. Survey, Surv. Comm., Rept. 1910-1912, pp. 91-107. Harrisburg, 1912.

[27] Lesley, J. P., Geology of Pennsylvania; Pennsylvania Second Geol. Survey, Summary Final Report, vol. II, p. 962, Harrisburg, 1892.

PHILADELPHIA COUNTY

Gordon[28] gives Fairmount Park and Mt. Airy as localities where the rare lead bearing minerals of uraninite and gummite have been found. Galena, sphalerite, and pyromorphite have been found at Falls of Schuylkill.

SCHUYLKILL COUNTY.

Genth[29] reports the finding of minute quantities of galena in a shaft of the Philadelphia and Reading R. R. Co. near Pottsville.

SULLIVAN COUNTY.

Within the Catskill group, which is mainly composed of sandstone and shale, there are some limestone beds that have been quarried from time to time. At the Millview quarry, about two miles north-northeast of Forksville, Sullivan County, Platt[30] describes the occurrence of some small specimens of galena.

UNION COUNTY.

Rogers[31] in describing the geology of Buffalo Valley states that "galena has been found in thin lodes traversing the calcareous spar-veins in the limestone; but no workable vein has ever been discovered."

YORK COUNTY.

Sphalerite or sphalerite and galena have been found sparingly in association with calcite or dolomite in small fracture veins in limestone quarries in the vicinity of Hallam and York. Jandorf[32] has listed a number of these occurrences.

The minerals occur as cleavage fragments encrusting minute cavities in the limestone, and not as crystals. Both sphalerite and galena have been recognized in the B. H. Stoner quarry 1¼ miles southwest of Hallam, in the York Stone and Supply Co. quarry 1¼ miles northwest of York, and in Cunningham Brothers quarry 2 miles west of York. Sphalerite has been found also in the quarry of the York Valley Lime Co., 1¼ miles west of Hallam, of the Emigsville Quarry Co., at Emigsville, of the Union Stone Co., 3/8 mile north of New Holland.

Eyerman[33] says that small quantities of galena have been found near Frystown.

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[28] Gordon, Samuel G., op. cit. pp. 37, 134, 140.

[29] Genth, F. A., Mineralogy of Pennsylvania: Pennsylvania Geol. Survey, Rept. B, p. 11, Harrisburg, 1875.

[30] Platt, Franklin, Geology of Lycoming and Sullivan Counties: Pennsylvania Second Geol. Survey, Rept. GG, p. 222, Harrisburg, 1880.

[31] Rogers, H. D., Geology of Pennsylvania: vol. I, p. 460, Philadelphia, 1858.

[32] Jandorf, M. L., York Valley limestone belt in York County: Pennsylvania Top. and Geol. Surv. Comm., Rept. 1910-1912, pp. 91-107. Harrisburg, 1912.

[33] Eyerman, John, Mineralogy of Pennsylvania, pt. I, p. 4, Easton, 1889.

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